DOCUMENT RESUME

ED 300 219 SE 049 714

AUTHOR Preuss, Karl-Heinz, Ed.; Simen, Rolf H., Ed.
TITLE The Federal Republic of Germany: A Land of Top-Ranking Research.
INSTITUTION Inter Nationes, Bonn (West Germany).
PUB DATE 86
NOTE 117p.; For related documents, see SE 049 715-717. Translation by Brangwyn Jones.
PUB TYPE Reports - Descriptive (141)

EDRS PRICE MF01/PC05 Plus Postage.
DESCRIPTORS Biological Sciences; Chemistry; Earth Science; *Foreign Countries; Physics; Program Content; *Program Descriptions; Research; *Research and Development; *Research Projects; *Science Programs; *Scientific Research
IDENTIFIERS *West Germany

ABSTRACT

Research and technology in the Federal Republic of Germany enjoy international distinction in many fields; indeed, German achievements in highly important areas have set new standards and influenced research and development world wide. This applies in equal measure to the natural sciences, the humanities and, in particular, to the applied engineering and biotechnical sciences. The carefully selected and representative examples given in this publication provide an overview of outstanding achievements by German Researchers and research institutions. Thirty-one research projects are highlighted in this book, dealing with: (1) such equipment and technologies as the synchrotron, nuclear fusion, transportation (railways), and mining; and (2) such topics and disciplines as biomagnetism, subatomic physics, radio astronomy, the earth's upper crust, ancient carthage, human though processes, synergetics, and a computer model for world politics. In each synopsis, a brief history and a discussion of the purposes and achievements of the project are included. (CW)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

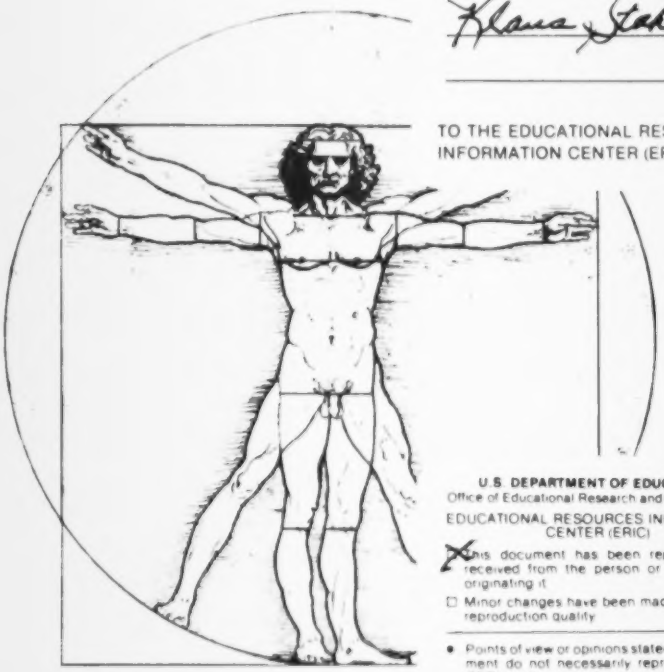
ED300219

Edited by
Karl-Heinz Preuß and Rolf H. Simen

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

Klaus Stahl

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."



U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☒ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

The Federal Republic of Germany:
A Land of
TOP-RANKING RESEARCH

SE 049 714

Research and technology in the Federal Republic of Germany enjoy international distinction in many fields; indeed, German achievements in highly important areas have set new standards and influenced research and development worldwide. This applies in equal measure to the natural sciences, the humanities and, in particular, to the applied engineering and biotechnical sciences. The carefully selected and representative examples given in this publication provide an overview of outstanding achievements by German researchers and research institutions.

The Federal Republic of Germany: A Land of Top-Ranking Research

Edited by
Karl-Heinz Preuß and Rolf H. Simen

1986 INTER NATIONES BONN

4

Translation: Brangwyn Jones

Published by Inter Nationes, Bonn 1986,
with the kind permission of
© Verlag Deutscher Forschungsdienst,
Forschungsdienst GmbH, Bonn-Bad Godesberg

Typography: Dieter Hüsken
Cover illustration: Atelier Hofer

Production: Nettesheim Druck GmbH, Cologne

Printed in the Federal Republic of Germany

CONTENTS

Preface 7

A quarter of a century of particle physics has made the Deutsches Elektronen-Synchrotron in Hamburg a world-renowned research centre:
Penetrating the Innermost Parts of Matter 11

A large research installation will help deepen knowledge on the correlations and essence of energy and matter in a new way:
HERA and the "Colours" of the Microworld 14

Scientific experts from the Gesellschaft für Schwerionenforschung (Society of Heavy Ion Research) in Darmstadt are looking for secrets beyond the limits imposed by Nature on the diversity of chemical elements. They will soon have new equipment to fulfil this task:
A Synchrotron for Germany's Alchemists 16

Researchers at the Physikalisch-Technische Bundesanstalt (Physical-Technical Federal Institute) have designed a unique laboratory to penetrate the world of biomagnetism which is an exceptionally complex field due to the demands it places on measuring techniques:
The Giant Cube in Berlin 19

Klaus von Klitzing was awarded the 1985 Nobel Prize for Physics for his trailblazing discovery of the quantized Hall effect. It permits an unprecedentedly accurate determination of atomic fine-structure constants, setting a new standard for ohmic resistance:
Catching up with Nature's Tricks Once More 23

In years of intensive cooperation, mechanical engineers, physicists and medical experts paved the way for the worldwide triumphant march of a new and extremely gentle therapeutic technique:
Shock Waves vs. Kidney Stones 26

In the endless war on pathogenic agents, which are defending themselves more and more effectively, researchers at the Gesellschaft für Biotechnische Forschung (Society of Biotechnological Research) in Braunschweig are developing a new arsenal of weapons:
Antibiotics from Gliding Bacteria 29

A German Nobel Prize winner has played a major part in a development which sets new standards in diagnosis and therapy and the full consequences of which cannot be fully predicted yet:
Living Probes for Biochemistry 32

The fact that an artifical heart is not the only hope for persons with a severe heart condition was demonstrated by researchers at the Rheinisch-Westfälische Technische Universität Aachen (Rhenish-Westphalian Technical University) with their now universally acknowledged developments:
Reconvalescence for the Severely Ill Heart 36

The progress in the special research project for the realization of controlled nuclear fusion at the Max-Planck-Institut für Plasmaphysik (Max Planck Institute of Plasma Physics) in Garching has been internationally acclaimed as "superproportional":
Artificial Solar Fire for the Earth 40

The Kernforschungszentrum (Nuclear Research Centre) in Karlsruhe has made great progress in developing new technical processes for taming solar energy:
New Technology for the Fusion Reactor 44

With their TEXTOR installation, fusion researchers at the Kernforschungsanlage Jülich (Nuclear Research Centre) have developed an experiment of particular importance for concrete progress along the path to the fusion reactor:
The Flagship of the Jülich Fusion Researchers 47

A shut-down nuclear reactor has acquired a surprisingly high value for nuclear technology as a whole in a unique experiment:
Sparking Catastrophes in the Name of Safety 51

It has long been common knowledge throughout the world that "Transrapid 06," hovering over magnetic fields, is adding a new chapter to the history of the railways on a test track in the German Emsland:
The Railway Is Beginning to Fly 54

In the opinion of experts, the new high-speed train of the Deutsche Bundesbahn (German Federal Railways), ICE, is by far the most modern train of its type in the world. At the moment ICE only stands for "Intercity Experimental." When it begins regular service in 1991 on new high-speed tracks, however, it will stand for "Intercity Express":
Half the Speed of an Airplane ... 57

A new type of mechanics, whose triumphant victory is beyond doubt, has been developed from the increasingly refined manufacturing processes for highly-integrated electronic circuits, of all things:
Entering a Technical Wonderland 61

German experts hold a worldwide leading position in providing the most modern production plants with the highest degree of flexibility possible by means of the latest information technology:
Factory Control by Videoplay 63

In the worldwide intensive activity in the development of bioreactors, researchers at the Kernforschungsanlage Jülich (Nuclear Research Centre) have achieved a major breakthrough:
Amino Acids as Required 66

For the first time, researchers at Jülich have succeeded in reducing the processes involved in the origin of mineral oil and the formation of oil deposits to a calculable form which is of importance to both prospecting and geology alike:
How Oil Matures in the Computer 69

The Bundesanstalt für Geowissenschaften und Rohstoffe (Federal Institute of Geosciences and Raw Materials) has once again underscored its leading position by developing a method of detecting deposits of sulphide ore which has not only surprised the amateurs:
Geochemistry Helps in the Search for Ore 72

With an enormously challenging project, German geologists will now get a glimpse into the secrets of the earth's upper crust:
Germany Will Get a Giant Hole 74

Since its renaissance after World War II, German radio astronomy has made such major contributions that it now stands in the international front line:
The Other Face of the Universe 78

With its unlimited observation functions, even in the thermal radiation area, a large German telescope opens the road to completely new findings:
A Closer Look at the Stellar Nursery 83

With the help of two new solar telescopes on Tenerife, Canary Islands, German scientists hope to make important advances in solar physics and in the exploration of a merely average star which, however, is the only one close enough to earth to be studied:
Solar Research on a Volcanic Island 86

German archaeologists are making an important contribution to the clarification of the rise and decline of an ancient metropolis:
Carthage Rises from the Ashes 89

In their search for an ancient copper-smelting industry, known only from historical sources, researchers from the Deutsches Bergbau-Museum (German Mining Museum) in Bochum made a "surprising" discovery":
Makan: Legendary Land of Copper Discovered 93

In a joint German-German undertaking, scholars want to throw light on Goethe's time through the reality of his vocabulary:
The Linguistic Cosmos of a Classical Writer 96

Tübingen researchers are filling in one of the gaps existing in the allegedly well-charted map of the world in a unique manner:
Atlas of the Near East 100

If the organization of human thought processes were better known, the solution to many complicated problems of great importance for the earth could be achieved better and more comprehensively:
Project: Thinking in Systems 104

Distribution problems will not remain the world's cardinal problems. In order to achieve this goal, Berlin scientists have designed a world computer model which includes politics for the first time:
Decision Aids for the World's Future 108

Mathematicians and natural scientists worldwide are increasingly concerning themselves with questions regarding the self-organization of matter. A German theoretician has made a major contribution to the clarification of these problems by developing a new scientific discipline called synergetics:
When Chaos is No Longer Chaos 111

PREFACE

"Neither Siegfried Balke, then federal minister of atomic and hydraulic energy, nor Max Brauer, then mayor of Hamburg, could imagine which kind of adventure of the human mind they started when they signed an agreement establishing DESY (Deutsches Elektronen-Synchroton) on December 18, 1959. Basically, the facility represented an attempt to catch up with the high level of American research following 25 years of dictatorship, war and reconstruction, which had paralyzed scientific activity in Germany. Furthermore, the new institution was intended to provide better academic training opportunities and encourage industry to realize outstanding achievements.

In retrospect, all of these goals seem to have been accomplished. In fact, the Federal Republic of Germany did more than meet world standards: today, it is one of the few countries achieving outstanding results in the field of physics with high-energy particle accelerators. Scientists from all over the world now come to Hamburg to participate in research projects which cannot be done elsewhere."

This quotation from Pedro Waloschek's article in this brochure on the early days of particle research in Hamburg and the scientists' boldness can be regarded as symbolic of the renaissance and subsequent development of other German research institutes. It must not be forgotten that DESY, one of the thirteen large research centres in the Federal Republic of Germany today, is only one of a carefully selected and, at the same time, representative examples of current research providing a glimpse into the supreme achievements of German researchers and research workshops.

Research and technology in the Federal Republic of Germany not only enjoy an internationally high esteem in numerous fields, but they have also led to a breakthrough in major achievements world-wide. Thus, they have set new standards and exercised a universal influence on research and development.

When, on October 16, 1985, the eyes of the scientific world

turned towards Stockholm where the Swedish Academy of Sciences had decided to award the Nobel Physics Prize to Klaus von Klitzing, a German, this was not only an award for outstanding accomplishment in basic research. The discovery of a new macroscopic quantum effect by Klaus von Klitzing which promises deeper insight into natural laws by making considerably more accurate measurements of a natural constant possible also contributes to semiconductor engineering, the basis of modern micro-electronics.

In an article in the German weekly "Die Zeit," which described the closing of the gap between basic and applied research, von Klitzing's colleague Hans Joachim Queisser writes: "Modern micro-electronics is the result of manifold research according to strict, scientific methodology; all further developments in physical science can only be achieved by means of a sound, theoretical basis, irrefutably verified in experiments."

Klaus von Klitzing's discovery is not only an example of how fluid the dividing lines between basic and applied research can be, but it also shows that research is of an international rather than a national nature. Researchers throughout the world have concerned themselves with the German physicist's discovery and quickly realized its practical applications. The "quantized Hall effect" discovered by von Klitzing has, for instance, made it possible to determine an ohm, the unit used for measuring electrical resistance, with unprecedented accuracy, prompting major national laboratories for weights and measures (for example, the Physikalisch-Technische Bundesanstalt Braunschweig, Federal Republic of Germany) to enter the scene rapidly.

Klaus von Klitzing's scientific achievement also illustrates quite clearly the extent to which a far-sighted research policy and reasonable cooperation concerning various research-promotion measures can set the course for scientific progress. Klaus von Klitzing made his discovery under a Heisenberg Programme grant from the Deutsche Forschungsgemeinschaft (German Research Association), the central, autonomous organization supporting science in the Federal Republic of

Germany. The main goal of this programme, named after German physicist and Nobel laureate Werner Heisenberg, is to promote highly-qualified young scientists. Furthermore, Klaus von Klitzing made his discovery as a guest researcher at the Grenoble-based intense-field magnetic laboratory belonging to the Max-Planck-Institut für Festkörperforschung in Stuttgart. This institute was set up by the Max-Planck-Gesellschaft primarily to provide solid-state research in the Federal Republic of Germany with new impulses. This society, which promotes science in the public interest, receives 50 percent of its funds from the federal government in Bonn and the federal states. The Magnetic Laboratory in Grenoble, which is run jointly by the Max-Planck-Gesellschaft and CNRS, its French sister organization, was in the beginning given very generous financial assistance from the Hannover-based Stiftung Volkswagenwerk, Europe's largest scientific foundation.

According to an estimate published by the Frankfurt-based Battelle Institute in the spring of 1985, more than DM 53 million was spent on research in the Federal Republic of Germany in 1985. This was DM 3 million more than in 1984, representing an increase of 7 percent.

In an international comparison of funds spent on research and development (especially basic research which boasts of a long tradition in Germany) the Federal Republic of Germany leads the field world-wide. The Federal Ministry of Research and Technology, which coordinates the federal government's research promotion measures and plans and carries out its own promotion programmes, increased the share of its budget earmarked for basic research from 27.4 in 1982 to 34.5 percent in 1985. It intends to increase this level yet further.

Many of the national research institutes receiving financial assistance from the Federal Ministry of Research and Technology rank among the world's best: these include, among others, numerous Max Planck institutes, DESY or GSI, the Gesellschaft für Schwerionenforschung, and the Fraunhofer Gesellschaft, which plays a unique role between research and industry. Universities, however, continue to be the main loca-

tion of knowledge-oriented basic research. Many of the achievements of application-oriented research in the Federal Republic of Germany also rank well internationally: the leading position enjoyed by the Federal Republic of Germany in magnetic levitation, which is a highly promising technological sector of the future, is just one of many such examples.

The Editors

Man has always been fascinated by the problems concerning the innermost structure of things. Does matter consist of small elementary particles, which the Greeks called átomos, or can everything be further reduced ad infinitum? A tradition among German scientists, who successfully worked on this subject in the past, has now been resuscitated in Hamburg. This has now resulted in a prestigious international research facility:

Penetrating the Innermost Parts of Matter

Neither Siegfried Balke, then federal minister of atomic and hydraulic energy, nor Max Brauer, then mayor of Hamburg, could imagine which kind of adventure of the human mind they started when they signed an agreement establishing DESY (Deutsches Elektronen-Synchrotron) on December 18, 1959. Basically, the facility represented an attempt to catch up with the high level of American research following 25 years of dictatorship, war and reconstruction, which had paralyzed scientific activity in Germany. Furthermore the new institution was intended to provide better academic training opportunities and encourage industry to realize outstanding achievements.

In retrospect, all of these goals seem to have been accomplished. In fact, the Federal Republic of Germany did more than meet world standards: today, it is one of the few countries achieving outstanding results in the field of physics with high-energy particle accelerators. Scientists from all over the world now come to Hamburg to participate in research projects which cannot be done elsewhere.

Visitors to DESY realize this as soon as they see the busy activity of the scientists, technicians and other staff there. They all live in a "special" world where nothing is sold, nothing is manufactured, and where the main objective is to broaden scientific knowledge. This knowledge is then made available without charge to the rest of mankind.

Within five years of being established, DESY proved just how sound the original idea was. The first particle accelerator, the "Elektronen-Synchrotron," having a diameter of 100 metres, was, at that time, the largest of its kind in the world. With its help, scientists were able to "look into" the smallest atomic nucleus, the proton, more deeply than ever before. The data obtained at that time is still the object of admiration today. It revealed the complicated nature of the proton's interior, that the proton had a kind of inner life.

Two years later, in 1967, these findings were further improved using still higher energies at SLAC, the American research centre in California. Finally, the present picture of the proton, which is built of three quarks, was obtained. This had previously been assumed by physicists working on particle creation on large proton accelerators in the USA and at CERN, the Geneva-based European Nuclear Research Centre. They had found a classification pattern for all these particles.

The classification pattern, which has now become clear, was not generally accepted in the late 1960s. New ways had to be found to prove whether the new scheme was nothing more than a mathematical model or whether the proton and many other known particles really did have an internal structure.

The experimenters and accelerator designers in Hamburg then set themselves a new task. In 1967, they proposed to build a "storage ring," in which electrons and their anti-particles, positrons, could be shot head-on at each other. They were searching for new ways to make progress in the investigation of the structure of matter. The reasons given for the construction of this machine, however, have very little to do with the interesting results, which were achieved first by the original storage ring and subsequently by a larger one. The new accelerators were named DORIS (Doppel-Ring-Speicher) and PETRA (Positron-Elektron-Tandem-Ring-Anlage) and began operating in 1974 and 1978 respectively. There was hardly enough room for PETRA on the DESY site; with a circumference of 2.3 kilometres, it surrounds all the buildings belonging to the DESY complex.

The completion of DORIS occurred at a particularly important time for particle physics. In November 1974 a revolution took place. A particle was discovered in the USA which literally forced scientists to accept the quark hypothesis. Using DORIS, scientists were able to begin investigating this interesting particle and its "excited states." The particle is known as J/psi, consisting of a quark and an anti-quark.

Following J/psi, "Ypsilon," another particle of similar nature, was discovered in 1977. In order to produce it in electron-positron collisions and to examine it more in detail, DORIS was improved and rebuilt in 1978 and 1982. Even today two large international research teams are devoting their energy to these interesting problems. This is one of the major contributions being made to understanding the very strong forces which hold the quarks together, not only in the J/psi and Ypsilon particles but also in the stable matter surrounding us.

Apart from the groups working at DORIS, five other international research teams have been working with the PETRA ring since 1978. PETRA is the largest machine of its kind in the world. It can achieve energy levels which make it possible to produce particles equivalent to about 50 proton masses. At these energies it was possible to verify accurately some effects of the so-called "weak forces," years before the carriers of these forces were discovered at CERN. Another discovery using the storage ring PETRA proved even more spectacular. It was possible to observe clearly the carriers of the strong forces acting between the quarks, the "gluons."

In 1984, exactly 25 years after its foundation, DESY started a new and exciting venture. It is called "HERA" (Hadron-Electron-Ring-Anlage), a storage ring system in which by 1990 electrons and protons can collide head-on at the highest energy ever attained. HERA will permit closer examination of the structure of these particles and the forces which act between them. This ambitious project is already attracting many physicists, engineers and technicians from all over the world to Hamburg.

Professor Dr. Pedro Waloschek

The research centre DESY (Deutsches Elektronen-Synchrotron) in Hamburg will be the first facility of its kind in the world to have a large accelerator in which high-energy electrons will collide with extremely high-energy protons. The accelerator, which is presently under construction, will provide information on particle physics which might lead to a breakthrough in the innermost secrets of matter and energy.

HERA and the "Colours" of the Microworld

In 1990, DESY will be equipped with a 6.4-kilometre-long underground storage-ring accelerator called HERA. The accelerator will require an investment of approximately DM 950 million. This new equipment should open up new areas of knowledge in a field in which exact science has to be combined with imagination.

Reduced to very simple terms, we may consider the innermost part of the world as consisting of "white" and "colourless" particles. The properties "white" and "colourless" mean that the particles can exist freely and that the white ones are subject to the nuclear forces, as opposed to the colourless, which are not. According to this interpretation, protons and neutrons are white and, as fundamental nuclear particles, they are "cemented" together by white mesons. However, electrons, which surround the nucleus, are colourless.

This symbolic colouration seems to be very confusing up to this point. The logical questions regarding the variety of colours found in the microworld heads quickly to a seemingly paradoxical reality of the unreal, at least if one wants to perceive the fascinating quality behind the matter-of-fact formulae.

White protons and neutrons, for instance, consist of three fundamental particles called "quarks," white mesons consist of only two quarks. Colours have been assigned to all these quarks. They are red, yellow and blue and thus no less colourful

17

than gluons, which hold the quarks together as the carriers of the so-called colour force. This colour force is the most powerful force known today in the universe.

According to the latest findings, nothing having this kind of colour can exist for its own sake, no matter how these quarks might be "seen" by a human being shrunk to the size of a "quantum" inside a proton, neutron or meson. Seen from "outside," they are white entities. Thus, if they are coloured, they seem to lose all right to exist in the material world. It reminds us of sunlight which does not represent a colour in itself, although it contains all colours.

The innermost structure of this strange microworld of matter is far from being understood. A lot of research has to be done in this area in which reactions happening in the microworld can be observed and measured. It has been found that all elementary particles are either "white" groups of quarks, of which there are a total of six different types, or "colourless" leptons, of which there are also six types. The question of whether there are more quarks and leptons or whether all these particles can possibly be traced to even smaller components is one of the puzzles concerning the structure of matter which is still unresolved.

It is precisely in this area that experts hope HERA will provide a major breakthrough. Protons consist of quarks, while electrons are leptons. Thus, this large machine will enable experts to examine the reactions between quarks and leptons at previously unattained energy levels, and consequently study the reactions between the coloured and colourless fundamental particles of our world.

These reactions (head-on collisions between protons and electrons) will occur in four sections of the 6.4-kilometre-long double ring. The protons will be travelling with an energy of 820 billion electron volts (GeV) against electrons at 30 GeV. Both protons and electrons will be moving at marginally less than the speed of light (ca. 300,000 kilometres per second).

The processes resulting from these high-energy collisions may possibly yield information concerning the structure of

quarks and electrons down to an order of magnitude of about 10^{-17} centimetres, that is the hundred millionth part of a thousand millionth of a centimeter. Furthermore, key findings are expected for a theory that may be universal and could include all known forces, even gravitation, which remains a sealed book.

This new machine is in its way roughly fifty times more effective than SLAC, the impressive linear particle accelerator with a length of 3.2 kilometres in California, USA. The fact that the largest refrigeration plant in Europe will have to be built for HERA's supraconductive magnets illustrates the advantages brought about by challenging technology and industry in areas which, at first glance, are not usually associated with research of this kind.

Rolf H. Simen

Scientific experts at the Gesellschaft für Schwerionenforschung (GSI) in Darmstadt (Society for Heavy Iron Research) have succeeded three times in generating new chemical elements for the lightning period of a mere few thousandths of a second. They have also been able to provide irrefutable proof of the elements 107 and 109 (1981 and 1982) and the element 108 (1984). These elements are much heavier than uranium (with the corresponding atomic number of 92), with which nature (at least as far as earth is concerned) has imposed a limit on its variety of elements:

A Synchrotron for Germany's Alchemists

The world-wide sensation of these achievements was prompted by UNILAC, a heavy-ion accelerator. It is the most efficient device of its kind in the world and, moreover, has been functioning without a hitch for the last ten years. Now this 120-

metre-long linear particle accelerator for heavy particles is to become part of a much more efficient research plant, which, at a cost of DM 275 million, is to be completed by 1989. It will also safeguard the leading position internationally of German heavy-ion research in the future, a position which this area of research has acquired particularly during the last ten years.

Plans call for the construction of a so-called synchrotron, a circular accelerator with a diameter of 60 metres. UNILAC will, in this connection, be used as an "injector," i.e. a supplier of high-energy heavy-ion rays. It will shoot these rays into the synchrotron at 20 million electron volts per fundamental nuclear particle. There, they will be accelerated up to a factor of 100. The new and unique feature of this plant is the linking of the synchrotron with a storage ring, for only through this link can the best-possible use of one or two heavy-ion rays be achieved in the experiments.

In a certain sense, the heavy-ion researchers at the GSI in Darmstadt are indulging in modern-style alchemy and not only that. It is no problem for them to make gold out of copper and tin, albeit in quantities of several hundred atoms per second.

This is made possible by performing surgery of sorts on atomic nuclei, whereby the composition of the protons and neutrons of the atomic nucleus in question can be modified. If one adds 50 protons of tin to 29 of copper, one has a core of 79 protons, i.e. gold. An operation of this kind is performed with a high-energy ray and is based on the very reasonable assumption that the tiniest basic particles of chemical elements can best be enlarged, influenced, shattered, modified and examined in a variety of ways by employing particles of a similar kind.

Accordingly, heavy ions are heavy atoms up to and including uranium which have largely been stripped of their electron shell and are thus electrically charged. Since they are electrically charged, they can be accelerated by electric fields and caused to interact at a precisely calculated impact velocity with identical or other atoms located in a specific target area. In this way heavy-ion physics investigates, in the widest sense, the

manifold reactions which occur when high-energy ions pass through matter.

The results obtained are not only sensational because of the successful synthesis of elements 107, 108 and 109, which, incidentally, still have not been given names. Their brief "spell of life" is dominated by the intriguing question as to why nature chose uranium, of all elements, as the heaviest element to conclude its creative activity on earth. There is yet another question: Just how far will science be able to approach the frontiers of the material world? There are those theoreticians who continue to assume the presence of this or that island of material stability in the sea of Mother Nature's possibilities, such as long-life, super-heavy elements in the region of atomic number 114 and, even more daring, atomic numbers in the region of 164.

But the proposed extension of the chemical element system also requires examining the structure of the atomic nuclei and trying to identify the forces holding the nuclei together. In 1981 a new type of radio-activity was discovered at GSI while synthesizing and observing the decay of neutron-starved nuclei. This so-called proton radio-activity, a process in which protons are ejected out of the basic state of a nucleus, revealed a new limit to the stability of atomic nuclei.

It even became possible to create things which do not exist, including an atom with the unbelievably high number of 188, i.e. a super-heavy phantom atom. It was generated for a short time following the collision of a heavy ion with another atom during which the two ions united under a joint electron shell. Initial indications of a "collapse of the vacuum" were discovered as far back as 1980 while examining highly intense electric fields which had been created in this manner.

At the enlarged plant, research will primarily be devoted to nuclear matter itself. Here, three fundamental forces are of special importance. They are known as strong, electromagnetic and weak interaction. Together with gravitation they determine the appearance of the entire material world. By bombarding heavy atomic nuclei with high energy-laden heavy ions of

this type in the new plant, scientists hope to be able to observe reactions which may possibly point to hitherto unknown properties of nuclear matter. Other projects call for compressing nuclear matter to a level at which study of astrophysical processes, such as the genesis of a neutron star, will be possible.

One of the practical successes of GSI's activities is evident from the fact that heavy-ion rays can, among other things, drill the finest microscopic hole imaginable to date. It will thus be possible to produce filters to separate bacteria and even viruses. But the most important application of this process may be something already regarded as feasible, i.e. the ability to directly measure the deformability of red blood corpuscles. It is also within the realm of possibility that a new and highly effective process will be developed which would make the diagnosis of blood disorders quicker and more reliable, namely a sort of "security check" for blood.

Rolf H. Simen

Routine measurements of action currents in the brain, heart and muscles are an important source of diagnostic information in medicine. However, live tissue not only generates electrical currents but also magnetic fields coupled to these currents. These magnetic fields are another source of valuable information on the functional state of organs. A special measuring cubicle, which was designed by the Physikalisch-Technische Bundesanstalt (Physical-Technical Federal Institute) and is unmatched worldwide, provides the fundamental requirements for making decisive progress in the field of biomagnetism:

The Giant Cube in Berlin

Even the most up-to-date encyclopedias have little information to offer on the phenomenon of biomagnetism. The most one is likely to find are references to the magical notions held

by hypnotist and magnetist Franz Anton Mesmer (1734 – 1815) and his successors. The fact that scientific biomagnetism is still in its infancy stems mainly from the exceptional weakness of the human body's magnetic fields, which rendered the task of proving their existence more than difficult. Cardiac fields, which are of interest to heart specialists, have a strength of no more than a ten to a hundred millionth of the earth's magnetic field. Up to about fifteen years ago they were practically unmeasurable.

This seemingly hopeless situation, however, changed in 1963 when Brian Josephson, a British scientist who was later awarded the Nobel Physics Prize, discovered the following: electric current flows without any dissipation across a thin insulating layer between two superconductors, provided this layout is cooled down to temperatures near the absolute zero point. However, the absolute zero point (– 273.15° Celsius or Kelvin 0) is unattainable. But since this current via a "Josephson contact" is strongly influenced by magnetic fields, highly sensitive magnetic-field measuring instruments, i.e. magnetometers, can be designed.

As this process takes place in a literally invisible microscopic area (the thickness of a contact of this kind is about one millionth of a millimetre), it has become possible only of late to manufacture serviceable elements and develop the complicated electronic equipment required for the detection and evaluation of their tiny measuring currents.

But these achievements alone are by no means enough for the exploration of biomagnetism. The highly sensitive measuring system, with which scientists can approach the limits of what can theoretically be measured, is extremely susceptible to stray fields such as the earth's magnetism, magnetic fields created by electric circuits and appliances, and even fields created by the measuring apparatus itself.

In order to eliminate external fields of disturbance, a measuring cubicle was built at the Berlin laboratory of the Physikalisch-Technische Bundesanstalt. It is by far the best-screened cubicle in the world.

A special chamber had to be built to accomodate this giant cube which has an edge length of about six metres. The measuring cabin proper is located inside. It is also cube-shaped, has an edge length of 2.3 metres, and consists of 1.5-centimetre-thick copper. It is enveloped in six sheet-metal wrappings of a special alloy, each several millimetres thick and separated from one another by 20-centimetre-thick layers of rigid expanded polyurethane. This cube, weighing some 40 tons, reduces external stray fields to less than one ten-thousandth of their original level. It thus guarantees a superbly "calmed-down" environment for the sensitive biomagnetic measurements undertaken inside.

Measuring the heart beat of an unborn child in the mother's womb is a good and empirically proven example of the efficiency of the magnetic measuring method. For reasons still unknown, the baby's heart beat disappears in the 30th week of pregnancy if the usual electric measurements are taken. In the case of magnetic-field measurements, however, each single heart signal is clearly distinguishable. A typical example of the work being done by the Berlin laboratory is the detection of marked changes in the magnetic fields of patients who have been revived after cardiac arrest. Similar changes were found in other patients who, because of these changes in the magnetic field, run the risk of sudden death. By using the Berlin magnetic measuring method, these patients can be singled out for therapeutic treatment.

Basically, there are two distinct fields in which biomagnetism might acquire great importance. The first area includes clinical diagnosis in cardiology, neurology, pneumology, obstetrics, and several other areas. The heart, for example, is a muscle which virtually functions independently of the rest of the body. This arises through its own independent excitatory system in which disorders can assume extremly dangerous forms. Standard diagnostics relies largely on the use of catheters which are inserted into the heart via the vascular system.

This method is risky and causes the patient discomfort. By resorting to biomagnetic methods (which are completely

"bloodless"), increasing success is being achieved in diagnosing the causes of defects in the excitatory system leading to much-dreaded and dangerous disturbances of rhythm. The possibility of localizing areas with defective functions is also being tried out successfully in cerebral diagnostics. In this area, one of the areas studied concerns the identification of the foci triggering epileptic attacks.

Another example involves thalassemia, also known as Cooley's anemia, which is not uncommon in Europe. It leads to anemia and subsequently causes the iron content in the liver to rise to a poisonous level. Normally, this effect is diagnosed by means of a liver biopsy. For some time now, however, a Case Western University clinic in Cleveland, Ohio, has been experimenting with a biomagnetic system to establish the iron concentration level in the liver.

The second field in which biomagnetic methods could prove rewarding is basic physiological research. Many organic processes, right down to cellular functions, have yet to be analyzed. Here, biomagnetism might lead to important revelations, as a number of projects have already shown.

For the most part, however, the possibilities briefly outlined here remain future dreams at this point. For one thing, the method is still too costly for hospital routine, and secondly, the bases of biomagnetism are still unexplored. With a few exceptions, little is known about the allocation of specific magnetic fields to well-known functional processes. The Berlin measuring chamber and the measuring and diagnosis techniques developed there may, of course, soon change this situation.

Dietrich Zimmermann

Fundamental constants "are like fingerprints in the creative process, suggesting the existence of even farther-reaching elementary natural laws." This was aptly stated in the 1981 Year Book of the Max-Planck-Gesellschaft (Max Planck Society). The publication also contains a report on Klaus von Klitzing's sensational discovery of the quantized Hall effect, resulting from research undertaken in 1980. These findings have now earned him the 1985 Nobel Prize for Physics:

Catching up with Nature's Tricks Once More

Through his work, Professor von Klitzing, a member of the directorate of the Max-Planck-Institut für Festkörperforschung (Max Planck Institute for Solid-State Research) in Stuttgart, opened up a surprising, new path for a hitherto unsuspectedly precise determination of the fundamental constant alpha which was first discovered by Arno Sommerfeld, the Munich physicist, in 1916 and which plays an extremely important role in physics. The fundamental constant is the measurement for the strength of electromagnetic interaction. It occurs wherever atoms transmit signals or wherever these signals affect atoms. Its numerical value is 1/137,036 and, as a so-called fine-structure constant, it determines the entire atomic structure.

At the same time, von Klitzing's discovery offered a new possibility to determine, using fundamental constants, what is known as "standard" in electrical resistance, which is also of utmost importance. Georg Simon Ohm (1787–1854) and others discovered that electrical resistance equals tension divided by strength of current. But this law had always proved problematic whenever an attempt was made to determine accurately the unit of this resistance named after Ohm. From 1908 to 1946, the "international ohm", a standard which is not used anymore, was defined as the resistance "which a constant electric cur-

rent experiences through a barometric column with a mass of 14.4521 grammes of constant cross-section and length of 106.300 centimetres at the temperature of melting iron." This resistance depended on the purity of the mercury and a number of uncontrollable influences, thus illustrating the problem of realization and consistency of a physical unit, in this case the ohm.

As has often been the case in the history of science, Klaus von Klitzing had originally wanted to investigate something else when his attention was drawn to the new phenomenon he had encountered. Under a grant from the German Research Association's "Heisenberg Programme," von Klitzing had left the University of Würzburg, where he had completed his doctorate under the aegis of Professor Gottfried Landwehr in 1972, to work as a guest researcher at the Intense Field Magnetic Laboratory in Grenoble. This installation is operated jointly by the Max-Planck-Gesellschaft and the CNRS, its French equivalent, and was supported generously in its beginnings by the Volkswagen Foundation. Professor Landwehr was put in charge of this laboratory at the time, and it was there that von Klitzing wanted to investigate the surfaces of semiconductors through the behaviour of electrons under extreme conditions. For this purpose he used the effect discovered in 1869 by the American scientist Edwin Herbert Hall (after whom the discovery is named) which basically can be taken as the measure for a concentration of charge carriers such as electrons. This effect manifests itself when a magnetic field is set to a live conductor at a right angle to the direction of current flow. As a consequence, the electrons are diverted from their normal path vertically in both directions, generating a voltage difference which can be used for measurements in each case.

For his application of the Hall effect von Klitzing was able to use incredibly powerful magnetic-field intensities at the Grenoble laboratory, namely up to slightly more than 20 Tesla. Exposing them to extremely low temperatures, he let them influence so-called oxide-silicon field effect transistors (MOSFET), the basic components of modern micro-electronics in

which the electronically-charged current carriers can only move in an extremely thin layer on the surface of a silicon crystal. It was then that von Klitzing, much to his surprise, discovered that nature not only makes jumps in the microcosmos: these jumps clearly take place in much larger configurations. The volatile change in the state of a particle's energy is one of the most important quantum phenomena in the microcosmos. Other dimensions in physics also occur exclusively as multiples of the smallest unit, e.g. the elementary charge as the smallest electrical charge. In von Klitzing's experiments the strength of the Hall effect also changed abruptly as the magnetic field increased, and the Hall resistance quantized from plateau to plateau.

The reason for this behaviour is that the electrons in the MOSFET elements are subjected to extreme conditions. The layers in which the electrons are able to move are so thin that only one electron "fits in." The powerful magnetic field, vertical to the layers, forces the electrons into such small circular paths that the energy jumps in the microcosmos become highly evident. The result is that the quantized Hall effect necessarily depends on two elementary fundamental constants, namely on the Planck quantum of action and the numerical value of the electronic charge. Thus the quantized Hall effect was discovered. The fine-structure constant alpha, which exclusively depends on the value of the quantized Hall resistance, can now be determined directly down to about one millionth. Researchers are still working on defining the method, because in the past extremely cumbersome methods had to be employed which were not always free from error.

The measured electric "plateau resistance" in the case of these quantized Hall effects proved to be exactly 25,812.8 ohms or corresponded exactly to integral fractions of this value, which regularly occurs in quantum-mechanical jumps in nature. Shortly after this sensational discovery, experts from the Physikalisch-Technische Bundesanstalt (Physical-Technical Federal Institute) in Braunschweig, among others, became involved, since they now had a completely new means of absolute determination of electrical resistance at their diposal.

As far as the Klitzing quantum jumps are concerned, research has been carried on in the meantime: Dr. Horst Störmer, a former staff member at the Max-Planck-Institut für Festkörperforschung, who is currently working at the Bell Research Laboratory in Murray Hill, New Jersey (USA), and Prof. Dan Tsui have discovered additional gradations. We must now wait and see how the researchers will tackle this new challenge with physical facts, particularly since many theoretical issues have yet to be clarified.

Rolf H. Simen

German mechanical engineers, physicists and physicians have jointly designed a fundamentally new machine for the remote and almost painless demolition of kidney stones to a point at which it can now be used in hospitals. The triumphant march around the world of a new therapeutic technique has thus begun:

Shock Waves vs. Kidney Stones

This technique was designed by the Dornier System company in Immenstaad, Lake Constance, together with medical experts and doctors from Großhadern Hospital in Munich and the Institut für Chirurgische Forschung (Institute for Surgical Research) at the University of Munich. The first successful treatment of a kidney-stone patient was undertaken as far back as 1980. Today, the use of this kidney lithotriptor has become everyday routine in a number of German hospitals. It will soon become universal practice throughout the Federal Republic of Germany. The 50th device of this type was acquired by a hospital in Georgia, USA, in the spring of 1985. By late 1986 the Dornier Medizintechnik Company in Munich, which was especially set up to manufacture the kidney lithotriptor, will have delivered 200 of these machines to many countries throughout the world.

This new type of kidney-stone crusher, which was developed with substantial financial support by the Federal Ministry of Research and Technology, is based on the fact that brittle objects found in a liquid evironment can be worn down and shattered by shock waves. With the same precision required to ignite objects with a burning glass, the invading shock waves have to be focused exactly onto the kidney stone. Between 700 and 1,500 shock waves are necessary to shatter the stone.

The shock waves are created by an almost explosive-like vaporisation of water for which a spark discharge provides the energy. In order to achieve the pressure and tractive forces required to smash the kidney stone, the pressure waves must be concentrated under water by means of an elliptical, bifocal, concave mirror. The discharge electrode, which creates the shock waves, is located in the one focal point and the kidney stone in the other. This means that the patient must be positioned in such a way that the shock waves hit the kidney stone exactly. To that end, the kidney stone has to be located precisely by X-ray. As a result, the lithotriptor looks like an oversized bathtub. It has a bed which can be lowered into the water with the patient lying on it. The kidney stone is then demolished in about 30 minutes.

By mid-1985, 18,000 patients had been successfully treated in this way. The figure has considerably increased since that time and will continue to rise since lithotriptor centres throughout the world are taking in a total of about 1,000 patients a week. Medical experts have more or less agreed that some 80 percent of all patients who would otherwise have to undergo an operation can be helped in this way. Only about one percent of persons receiving this treatment require surgical removal of stones which have not been reduced sufficiently. In the case of complicated uric acid or cystine stones (cystine is a sulphurous amino acid), a combination of shock-wave crushing and medical dissolution can also achieve success.

In future shock-wave therapy will be of benefit not only to kidney-stone patients. New areas of application are already beginning to emerge: human gallstones, for instance, have been

exceedingly difficult to localize with X-ray under certain conditions, which presented a major obstacle prior to the application of the shock-wave technique. Yet even these difficulties do not seem insurmountable: after three years of preparatory research, a trial-appliance to shatter gallstones, designed by Dornier under the supervision of Professor Gustav Paumgartner of the Institut für Chirurgische Forschung at the University of Munich and based on the shock-wave principle, has made an initial breakthrough. Treatment of just a few patients was started in January 1985 and has already produced encouraging results. Following treatment, six out of eight patients were cured of their colic; four of them had no further identifiable traces of stones. True, the information gathered so far is still too limited to be able to make reliable forecasts about the projected application of the method in hospitals. It has not yet been determined what happens to the dustlike remains of pulverized gallstones in the body. Years of intensive research will undoubtedly be needed in this area.

Shock-wave experiments to revive heartbeat following cardiac arrest or to stimulate a pathologically slow heartbeat are promising. The shock fronts can be transformed into slower, energy-starved pressure waves which no longer damage the tissue if it contains air. The risk of damaging the tissue would exist if the lungs came into the proximity of a stone-crusher, which, incidentally, has also been one of the problems with the demolition of gallstones.

Dornier has already designed a prototype which operates on less energy and which has been clinically tried out several times to treat cardiac arrest. Once this system has proved its usefulness it could replace heart massage. Currently, cardiac arrest is also treated medicinally; this method, however, is not undisputed.

Professor Walter Brendel, director of the Institut für Chirurgische Forschung, who played a prominent part in the development of the new method, is convinced that the possibilities of shock-wave therapy have by no means been exhausted. Just as Wilhelm Conrad Röntgen's original disovery, which he named

X-ray, led to traditional diagnostic radiology, tomography and computer tomography, shock-wave therapy will also experience further development. After all, Brendel argues, it was not so long ago that many doctors considered it impossible to work for short periods in the human body with pressures around 1,000 bars without damaging the tissue. In the meantime, at least 18,000 kidney-stone patients, who have been treated in this way throughout the world, quite definitely serve as proof that the opposite is true.

Dieter Schwab/Rolf H. Simen

Scientists at the Gesellschaft für Biotechnologische Forschung (Society for Biotechnological Research) at Braunschweig-Stöckheim are in the process of tracking down a new group of antibiotic substances. They have already been able to announce important successes in this field:

Antibiotics from Gliding Bacteria

Some 6,000 to 7,000 antibiotics are known at the present time. About 150 of these substances from micro-organisms are used in practice, mainly to combat bacteria and fungi. New compounds are being feverishly sought by researchers. It has now become a matter of urgency to find new substances because many pathogenic agents are gradually becoming resistant to certain antibiotics. Furthermore, since the early days of antibiotic research, numerous other possible applications of biologically active substances have emerged, e.g. as feed additives, pesticides and other biocides, anti-tumor therapy, or pharmaceutical drugs.

The antibiotics used most commonly today are derived from just a few groups of micro-organisms such as actinomycetes and bacilli (both bacteria) or, as in the case of penicillin and cephalosporin, from lower fungi. In this connection, the "gliding bacteria" seem to be highly promising. They are being in-

vestigated by Professor Hans Reichenbach (microbiology) and Gerhard Höfte (chemistry of compounds) and their staffs at the Gesellschaft für Biotechnologische Forschung.

Unlike most other bacteria, which use flagella to swim around their habitat, gliding bacteria creep along the surface of the substrate on tracks of the slime they discharge. Although it has been known for some time that these organisms produce antibacterial substances, they have never been seriously investigated in this respect because their cultivation seemed too difficult. Only one relatively simple antibiotic form of a gliding bacterium of the genus lysbacter, myxin, was structurally determined in 1966. It is used today in veterinary applications.

The GBF microbiologists have been concerned with these problematic but highly promising bacteria since 1975. Research in Braunschweig soon concentrated on the myxobacteria, a group consisting of some 40 different species. These "slime bacteria" display unusual behaviour whenever their living conditions deteriorate. Cells come together, pile up, and form fruiting bodies, i.e. complex tree-like structures in which they wait for better times, protected by a tough skin. These "permanent colonies" can be cultivated without difficulty in liquid media, e.g. maize gluten, cornsteep liquor, and bacterial or yeast cells. The experts in Braunschweig have so far investigated 2,500 different strains of numerous species of gliding bacteria in regard to antibiotic substances.

More than half of them are myxobacteria which show an astonishingly high yield of positive strains: between 50 and 80 percent of the strains tested produced antibiotic activities. This represents a percentage which has hardly been attained by any of the other groups of organisms examined so far. This yield impressively emphasizes the importance of myxobacteria as the target group for the Braunschweig experts. The cytophago group of gliding bacteria, on the other hand, revealed much less antibiotic activity and, even more important, substances produced by them turned out to be chemically trivial and already known.

So far, 18 active agents with some 80 chemical variants have been isolated from a large number of the bacterial strains and have been carefully examined. Fifteen of these 18 basic substances turned out to be new. Not unexpectedly, it was found that many of the new antibiotics may be produced by strains of different species and even genera, and that different strains of the same species may synthesize as many as two or three different antibiotics simultaneously.

This complex situation makes the isolation and identification of the active compounds difficult. Furthermore, the initial yield of interesting substances was very low, namely no more than 0.2 to 20 milligrammes per litre of culture solution. The experts even succeeded in growing some of the initially problematical myxobacteria in the GBF's largest bioreactor (with a capacity of 5 cubic metres) under production conditions. This was achieved in technical media, thus paving the way for future mass production. Further improvements in the mass production of active substances may be expected from basic research into the metabolism of myxobacteria, which is still largely unknown.

Several of the new substances do indeed exhibit interesting properties. Myxopyronin, like coralle-pyronin which it resembles, interferes specifically with ribonucleic acid synthesis (RNA synthesis) of bacteria, thus inhibiting their multiplication. Myxothiazol and stigmatellin efficiently inhibit cellular respiration in higher organisms, i.e. those above bacterial "level," as well as photosynthesis. Myxovirescin is particularly effective against Gram-negative bacteria. It inhibits growth by disturbing the cell wall structure. Since the structure of bacterial cell walls is fundamentally different from that of higher organisms, myxovirescin is non-toxic for the latter. There are few other known antibiotics which act in a comparable manner. At the moment, the most interesting myxobacterial antibiotic appears to be sorangicin, a highly effective inhibitor of bacterial RNA synthesis with an unusual chemical structure. It is active in the animal body without side effects.

There are a few problems, however, which still need solving

before these very promising new discoveries can be further developed. One of the most important issues is the question of the limited level of productivity. Significant progress in this direction has already been made, mainly through the selection of suitable nutrients or the use of mutant strains that are insensitive to the antibiotics they produce.

Another problem arises from the fact that several of these substances are active only in vitro under laboratory conditions but for one reason or other become totally neutralized when used in the animal. The Braunschweig team hopes to overcome this problem, too. Various chemical derivatives of myxovirescin are currently being synthesized in the hope of getting variants that are effective within the animal organism. Be that as it may, even when the last barriers have been removed, previous experience shows that it will take years before a new antibiotic can be practically applied.

Dr. Harald Steinert

One would little suspect that the somewhat sober term "monoclonal antibody" in fact represents a scientific breakthrough to a new type of biological probing into the finest functional correlations of life. Because of the very principle it is based on, it can probably not be surpassed as far as precision is concerned. Among other things, it might significantly advance cancer research. German scientists played a central role in achieving this breakthrough:

Living Probes for Biochemistry

It undoubtedly came as no surprise to the experts when, in 1984, the Nobel Prize for Medicine was awarded to three researchers who had particularly distinguished themselves in exploring the human body's defence system. Niels Kaj Jerne, a Dane, was honoured "for his theories on the specific structure and control of the immunological system." He is the pioneer

and outstanding theoretician in the field of modern cellular immunology. At the same time, he blazed a trail for the research work of Argentinian César Milstein and his disciple, Georges J. F. Köhler, both of whom shared this supreme scientific honour with Jerne.

Milstein and Köhler received the Nobel Prize "for the discovery of the principle of the production of monoclonal antibodies." It will be necessary to go into a little more detail to appreciate fully the background of this fascinating development. The word "clone" is used to describe a cell colony which has grown from a single cell. All the cells in a clone possess exactly the same genotype as the original cell. As a result, they are not only externally identical, but their internal, vital processes also follow the same patterns. If, therefore, a researcher is lucky enough to find a cell which produces an interesting substance in particularly great abundance, or if he succeeds in modifying a normal cell correspondingly by resorting to special tricks, care needs to be taken to see that it divides and multiplies. The result of this process is a clone, the cells of which display exactly the same properties as the mother cell. This procedure is also the basis for all biotechnical production processes using single cells.

A special group of substances formed by cells are antibodies. They play an important part in the defence systems of higher organisms, including human beings. Whenever pathogenic agents or other foreign substances invade the body, defensive reactions are triggered. Specific white blood cells produce antibodies. Antibodies are proteins which are designed in such a way that they can attach themselves to the foreign molecule in certain places. This coupling actuates processes leading to the disintegration of the foreign molecule.

One particular feature of antibodies is the fact that they react to one specific atomic group in the foreign molecule. This property makes antibodies highly interesting for biological and medical research since it enables experts to recognize molecules which have this structure, as well as cells bearing such molecules. This property even permits the separation of

these molecules from mixtures, particularly in cases in which they are few in number. The desire to be able to isolate a specific antibody in pure form is therefore understandable, but the path taken to fulfil this wish turned out to be unusually thorny.

The difficulties begin with the fact that the organism uses a large variety of antibodies to fight a foreign molecule. These include antibodies combating various structural areas of the molecule as well as other antibodies directed against identical atomic groups. It is assumed today that this multiple identification of a foreign substance considerably reduces the substance's "chances of survival." Whatever the case may be, antiserum obtained in the conventional manner always contains a mixture of many antibodies which are virtually inseparable.

This dilemma could be avoided if a single white blood cell could be isolated and prompted to form a clone. This would make the production of a single antibody type possible. César Milstein and Georges Köhler tackled this task in the Laboratory for Molecular Biology belonging to the British Medical Council, Cambridge, where they achieved a breakthrough in 1975.

Köhler, who is now director of the Max-Planck-Institut für Immunbiologie (Max Planck Institute of Immunobiology) in Freiburg and professor at the local university, united the antibody-creating lymphocytes of mice with tumour cells which were also taken from mice. He thus obtained mixed cells (hybrids) which manufactured antibodies and at the same time, as a contribution of the tumour cells, possessed unlimited viability and were thus able to multiply into a clone. Milstein, in whose laboratory Köhler worked from 1974 to 1976, had already achieved the fusion and reproduction of two antibody-producing tumour cells in the early 1970s. The decisive step toward using cellular hybrids, however, was the fusion of normal lymphocytes with tumour cells.

The complicated and sensitive process required to obtain monoclonal antibodies with special properties, which was developed by Köhler, begins by infecting a mouse with a sub-

stance foreign to its body in the initial experiments, for instance with the red blood cells of a sheep. Cells are extracted from the antibody-forming spleen and combined with the tumour cells of the mice. The result is mixed cells, from which clones can be formed following several stabilizing separations. These clones produce the required antibody. The cells multiply almost at will in nutrients or when injected into a mouse's body. If they are kept frozen they are just as vital and procreative after thawing as they were before.

Over the years, biochemists have learned how to obtain monoclonal antibodies against almost all substances which are regarded as foreign by animal bodies: proteins, carbohydrates, glycolipides, components of cellular surfaces, and viruses. The technique has been perfected to such a degree that it is increasingly becoming part of daily biochemical routine. It is already being used in manufacturing processes by several pharmaceutical firms in the Federal Republic of Germany.

Interferon is a striking example of what can be achieved with monoclonal antibodies. The production and purification of this protein, which is able to inhibit the multiplication of viruses, used to present great problems. Only when it was possible to produce antibodies against inferon did it prove possible to isolate this sensitive protein by fusing it with these antibodies. The Gesellschaft für Biotechnologische Forschung (Society of Biotechnological Research) in Braunschweig, in particular, has made a name for itself in the Federal Republic of Germany by producing interferon antibodies. This achievement has received international acclaim.

Another application in the medical field is a series of monoclonal antibodies which experts at the Deutsches Krebsforschungszentrum (German Cancer Research Centre) in Heidelberg and at Heidelberg University have produced. These antibodies attack the surface antigenes of leukemia cells and malignant lymph-node tumours. Since the phenotype and course of carcinoses can be very different, an accurate diagnosis is of paramount importance for further treatment. Various monoclonal antibodies are already available to make pre-

cise diagnoses. They are now being used as a matter of routine for the classification and type-specification of leukemic and lymph-node tumour cells.

Listing all of the possible uses of monoclonal antibodies would fill many pages. The spectrum ranges from blood-grouping to cell and immunological research to therapeutic applications. Experts are convinced that monoclonal antibodies will play an important role in biochemical research as a whole, particularly as highly specific "probes."

Dietrich Zimmermann

The blood pump designed at the Rheinisch-Westfälische Technische Hochschule (Rhenish-Westphalian Technical University) in Aachen to provide relief for diseased hearts has now become a universal household word. The team which developed it is so diverse scientifically that it ought to be considered a model for international research:

Reconvalescence for the Severely Ill Heart

The current goal of the experts in Aachen, who are working together on a special research programme sponsored by the Deutsche Forschungsgemeinschaft (German Research Association) is not an artificial heart. They are concerned with helping a sick heart which will provide relief for three to four weeks so that the heart can recover.

The greatest obstacle to developing auxiliary mechanical devices for the circulation system continues to be the fact that they eventually cause permanent damage to the blood. This problem has to be tackled in regard to flow and the artificial surfaces of such a system with which the blood comes into contact. This is particularly evident in the area of research in which Professor Holger Schmid-Schönbein, a physiologist in Aachen, is in-

-39

volved. The red blood cells, for instance, are literally crushed in the maelstrom of marked fluctuations in flow velocity. What is even more dangerous is the natural readiness of the blood platelets (thrombocytes), in the case of a fine vascular injury, considerably increasing the blood flow in limited local areas, to react in a thousandth of a second or so and trigger the coagulative sealing process. But they also react like that whenever they "collide" with an artificial system because of the nature of the blood flow, or when they interact in some other way with uncongenial surfaces. In the flow area this process primarily occurs in congestion points, i.e. places where the flow string runs into an obstacle and is literally brought to a halt. If these thrombocytes, once they are activated, are thoroughly mixed with other thrombocytes in the vortex areas, they produce active substances which cause the other thrombocytes to form clots. These clots (thrombi) are swept along by the blood and deposit themselves anywhere in the body, thus blocking the vessels. The great danger in this connection is the fact that these blood clots can form in tiny dimensions and great numbers. Although they can pass through the finest capillary system in the body, they gradually accumulate in lungs and kidneys to such an extent that dangerous functional disorders can occur. It has not yet been clarified why this happens.

Apart from this acute problem of microthromboses, it is common knowledge that artificial systems of this type harm the red corpuscles by constantly arousing the coagulative potential of the blood. This exhausts the blood. Consequently, at the present state of the art, it is not possible to implant an artificial system to help or even replace the heart's function for any length of time. The time limit for the traditional heart-lung machine, for instance, is about six hours; this period can be extended if the machine is only used as a pump – but not as a "lung" as well. In animal experiments using calves, blood pumps designed in Aachen have been implanted for up to five days. Heart and vascular surgeon Professor Bruno Messmer, who acts as the spokesman for the DFG special research programme, is in charge of these experiments. The goal of pro-

longed and less risky help for an ailing heart is still faced with many obstacles.

The pump itself is primarily intended to assist the left ventricle since the body's entire circulation is supplied by the left side of the heart; the right side supplies only the lungs. As a result, weak functional capacity and cardiac damage on the left side of the heart are much more common. A pump of this kind can offer the impaired left side of the heart a chance to recover, because it can be "hooked up" in such a way that it can bypass the left side and take over its functions to a large extent. In this connection there also are plans to use pulsating systems which are as realistic as possible: there are now several different prototypes which consist basically of a pneumatically-operated "heart muscle," an auricular chamber, and an arched outlet on the other side. These parts are connected with one another and controlled by artificial cardiac valves. The pumps are made of a special synthetic material, the valves (cast in one piece) are integrated into this "case" material. These systems are so sophisticated as far as flow is concerned that the blood passes through them quickly and as smoothly as possible. Congestion zones, vortex areas, and other trouble spots are avoided. The pumps are about twice the size of a fist. They are supposed to be used outside the body, according to the purpose they have to fulfil; they are connected to the body by two "synthetic blood vessels" in such a way that they bypass the heart.

Work has been in progress on such systems in Aachen since 1969. The level of knowledge involved is best illustrated by listing the institutes associated with this research team headed by Professor Egon Krause. Institut für Hydraulische und Pneumatische Antriebe (Institute of Hydraulic and Pneumatic Drive), the Rogowki-Institut für Elektronik (Institute of Electrical Engineering), the Institut für Kunststoffverarbeitung (Institute for Plastics Processing), the Aerodynamisches Institut (Institute for Aerodynamics), the Institut für Verfahrenstechnik (Institute for Materials Processing), and the Helmholtz-Institut (Helmholtz Institute). The Department of Cardiac and Vascular Surgery joined the team in 1981.

But this list is still not complete since the demand for a material which allows the blood to pass the artificial system as smoothly and safely as possible can be tackled in two ways that, in the final analysis, are not mutually exclusive. At Professor Georg Menges's Institut für Kunststoffverarbeitung, experts are continually working on perfecting synthetic components and their surfaces as well as on suitable heart valves. The second approach would require that these artificial surfaces be covered with living cell material which would not cause any harmful reactions in the blood as it flowed by. Pathologist Professor Christian Mittermeyer and his colleagues are working on this problem in Aachen. Their first success was the discovery of a special type of cell which can be used to cover the surfaces up to about one square centimetre even though these cells apparently do not grow around edges or corners. This research area has thus been mapped out, but it will involve enormous investment.

The many years of research effort show that the human heart is anything but just a pump which can be technically replaced without any problem. Even the "last but one" help for an ailing heart designed in Aachen will need a long time to be realized, although the goal has already been defined.

Rolf H. Simen

Inside the sun and other stars the lightest atomic nuclei fuse to form heavier ones. Yet these new nuclei are not quite as heavy as the sum total of the original particles, because part of the mass in such nuclear fusion processes is converted into energy. It is this fusion energy which enables the stars to shine for billions of years. Scientists are now imitating this phenomenon by devising similar processes to make this enormous energy source available on earth:

Artificial Solar Fire for the Earth

The principle of this kind of nuclear fusion which the research experts have modified for the earth consists in converting a mixture of deuterium and tritium, the heavy and superheavy isotopes of hydrogen (the lightest atomic nucleus), into a plasma state. In this state atomic nuclei can collide with each other since they are unshielded by the atomic electrons, which have been stripped off. The collisions must be extremely violent, however, if nuclear fusion is really to take place, creating helium from deuterium and tritium. This, in turn, is achieved by heating the plasma, which ensures that the plasma particles acquire high velocities.

This process calls for very high temperatures in the region of 100 million degrees Celsius. A reaction mixture with this astronomic temperature, however, must be prevented from coming into contact with the earthly material of the vessel wall; otherwise the material would immediately vaporize. But since the plasma only consists of stripped atomic nuclei and electrons, i.e. electric charge carriers, an extremely powerful magnetic field can be applied in an attempt to confine it inside the vessel in a vacuum environment. In other words, it must remain "captured" as a freely suspended, super-hot reaction cloud under conditions where nuclear-fusion processes can take place and yield more energy than is needed to "tame" this cloud of energy. Only when energy is gained can one really talk of using energy from nuclear fusion.

When the enormous problems standing in the way of achiev-

ing controlled nuclear fusion are seen in this light, it is not surprising that experts reckon the first energy-producing fusion reactor will not be available until after the turn of the century. Currently, fusion research should be classified as objective-oriented basic research which will greatly benefit from intensive cooperation transcending laboratories and frontiers.

The Max-Planck-Institut für Plasmaphysik (Max Planck Institute for Plasma Physics) in Garching near Munich is the largest of the 20 institutes and laboratories working on the development of fusion technology in nine European countries. The 250 scientists working in Garching have been so successful that their share in the progress made in the field of fusion research and technology has been unanimously acknowledged as disproportionately large.

This share is likely to increase in the future when the WENDELSTEIN VII-AS and ASDEX Upgrade large-scale experiments begin in 1986 and 1988, respectively. These experiments are designed to test and further develop components which the present state of the art shows to be basic to subsequent reactor operation. This reactor operation will attain energy levels a good million times greater than those now possible with conventional "chemical" combustion. The basic requirement for this fusion process, however, is not simply that the deuterium-tritium plasma has a temperature of 100 million degrees Celsius; it must also have a sufficiently high density. This requirement further increases the difficulties facing development.

Back in the 1960s, Soviet researchers succeeded in confining plasma for several thousandths of a second at a temperature of 10 million degrees Celsius in a torus, i.e. a vessel resembling a car tyre. The plasma trapped in this toroidal machine, known as a "tokamak," represents the secondary winding of a large-scale transformer. When the current is increased in the primary winding of the transformer, a current is induced in the plasma; this heats the plasma and, at the same time, builds up a magnetic field in conjunction with the surrounding magnetizing coils. The resulting helically twisted magnetic field lines form an effective cage confining the plasma particles.

ASDEX, which was put into operation in Garching in 1980, is a tokamak. Its plasma ring has a diameter of about three metres and a thickness of 80 centimetres. In 1975 PULSATOR, the previous tokomak experiment at Garching, had clearly exceeded the "density limits" generally feared by the experts. ASDEX made it possible from the very beginning to manufacture remarkably clean plasma with temperatures of 30 million degrees Celsius and life spans up to 12 seconds. This was achieved with a "divertor," a system of auxiliary magnetic coils whose field diverts impurities in the plasma into side-chambers where they are neutralized on collector plates and then pumped off.

Allowed temperatures of 50 million degrees Celsius were reached through neutral-particle heating, in which hydrogen atoms are ionized, accelerated in electromagnetic fields, neutralized once more, and then injected through the magnetic cage into the plasma. It was thus possible with very strong neutral-particle heating to enter a region with very good energy confinement – an achievement which put an end to a long period of stagnation in fusion research.

Investigation of instabilities and perturbations in plasma and the search for possible ways of controlling plasma build-up and the plasma properties are the main objectives of fusion research more than ever. In this connection, one of the most efficient methods is to irradiate the plasma with high-frequency waves which systematically excite and heat the electrons and ions spiralling round the magnetic field lines. In applying high-frequency heating, the Munich scientists have again performed pioneering work.

Further development of the highly successful divertor principle will be pursued in ASDEX Upgrade, the main components of which are currently being manufactured. Although its plasma ring is only slightly thicker than that of ASDEX, the plasma will have a higher energy flux, particularly in the boundary region. This will create conditions approaching those of a future fusion reactor and allow the investigation of interaction between the extremely hot plasma and the wall, of con-

tamination by wall material, and of the effectiveness of the divertor in regard to NET. NET will be the next European experimental reactor and successor to the JET (Joint European Torus) experiment at Culham, U. K. ASDEX Upgrade is being given preferential support by EURATOM. The United States is also very much interested in joining the project.

Since it seemed for a very long time that a tokamak could only be operated in a pulse mode because of the transformer principle (whereas only continuous operation is suitable for commercial reactors), the stellarator line is also being pursued at Garching. In this type of fusion machine, no transformer is needed, and the confining helical magnetic field is only generated by currents in the magnetic coils surrounding the torus. These fusion machines get along without current in the plasma. In the WENDELSTEIN VII-A stellarator, which was recently shut down, it was possible to produce and maintain high-quality plasma just by neutral-particle injection.

The plasma ring of WENDELSTEIN VII-AS, the follow-up stellarator experiment now under construction, has a diameter of four metres and a thickness of 40 centimetres. It is remarkable for two reasons: first, the torus is composed of five modules, and second, each of the nine magnetic coils belonging to a module has a different shape. The coils, designed on the basis of extensive calculations, are intricately distorted. The stellarator principle, almost abandoned in the USA years ago, now seems so promising in the wake of successful experiments at Garching that the experts are already engaged in studies of a machine with "reactor-relevant" dimensions whose plasma ring will be 51 metres in diameter and a good three metres thick. These projects will, of course, involve intensive international cooperation.

Dietrich Zimmermann

Next to the Max-Planck-Institut für Plasmaforschung (Max Planck Institute of Plasma Research) in Garching and the Kernforschungsanlage Jülich (Jülich Nuclear Research Centre), the Kernforschungszentrum Karlsruhe (Karlsruhe Nuclear Research Centre) is the most important address for fusion researchers in the Federal Republic of Germany. In Karlsruhe, experts are principally concerned with the development of superconductive magnetic coils for future large fusion reactors, as well as with problems of materials, the heating of plasma, the handling of tritium, the fuel for nuclear fusion, the fuel cycle, and remote control technique:

New Technology for the Fusion Reactor

Whereas research work in Garching is focused on plasma physics, the 200 or so scientific experts engaged in fusion research in Karlsruhe are engaged in developing the technique required for the construction of a fusion reactor. First of all, there are the powerful magnets required to confine the plasma which is heated to a temperature of 100 million degrees Celsius and consists of electrons and hydrogen nuclei. The particles move at such high speeds at this temperature that the surrounding material wall would simply vaporize if it were bombarded with them.

Experts believe that these magnetic fields in future reactors will have to be several hundred thousand times stronger than the earth's magnetic field, namely 12 to 14 tesla. In order to keep the required current consumption for the build-up of such fields within limits (JET, the European experimental reactor in Culham, U. K., needs a peak capacity of 700 megawatts for several seconds during each cycle), the researchers are taking advantage of the phenomenon of superconductivity. Conductors made of special niobium alloys are cooled down to almost absolute zero (- 273.15 degrees Celsius) using liquid helium. In this temperature range the ohmic resistance suddenly ex-

periences a complete collapse, and the high current levels of more than 10,000 amperes can circulate without loss in the coils.

In collaboration with the industry, the Kernforschungszentrum Karlsruhe first designed a superconductive D-shaped coil which is 5.5 metres high, 3.7 metres wide, and 60 centimetres thick. It has a 3.3 x 2.3-metre hole in the middle which is meant to hold the ring-shaped (toroidal) plasma container of a tokamak-type fusion reactor. At a later date, many coils of this kind will be needed to create a powerful and steady magnetic field in this torus. The basis of this superconductor are niobium-titanium filaments one hundredth of a millimetre in diameter. The filaments are embedded in copper and twisted and eventually shaped into finger-thick rectangular conductors. Twenty-three of these conductors are twisted round a steel band and encased in a helium-tight steel jacket. There are gaps between the conductors so that the cooling helium can flow through.

Since, at a later date, the coils will be exposed to forces of several hundered tons, an extremely high standard of robustness is required, down to the smallest welded and soldered joints. The coil, which was commissioned by EURATOM, is currently being tested at the Nuclear Research Centre in Oak Ridge, together with five other coils designed in the USA, Switzerland, and Japan. The goal of this Large Coil Task (LCT), a project set up by the International Atomic Energy Agency (IAEA) in Vienna, is to pave the way for the best-possible coil concept.

But not even highly powerful magnetic fields will be able to prevent the wall and plasma from interacting. Consequently, it is estimated that a good 20 percent of the fusion output must be taken up by the first protective shield. Hydrogen ions may knock atoms out of their shield, high-energy neutrons may dislodge atoms from their grid positions, the helium nuclei created during the fusion process may diffuse through the material and form gas blisters, and arc charges and heat shocks may develop. These processes would affect not only the stability of the wall

but also contaminate the plasma. Since experts still do not know enough about the behaviour of the materials, they are systematically examining steels and alloys with a zirconium, nickel, or vanadium molybdenum base as well as ceramics in simulation experiments. Thus, they hope to obtain the needed data to design an effective shield.

Another focus of research is the heating of the plasma to a temperature of some 100 million degrees Celsius. At this temperature, deuterium and tritium nuclei collide and fuse into helium nuclei, which create enough energy to keep the subsequent process self-sustaining from then on. This high temperature is reached by injecting neutral particles (highly accelerated deuterium atoms) or feeding in high frequency-radiation. This method has previously been demonstrated in experimental reactors. But since with large reactors at least 100 megawatts of electric power must be fed in for a period of ten seconds, there is still much work to be done in this area of research. Particular effort is also being devoted in Karlsruhe to the development of gyrotrons, transmitters in the frequency range of 150 gigacycles per second (Gc/s).

At present, there are barely more than theoretical approaches to solving the problem of how to "breed" the fusion component, tritium. This heavy hydrogen nucleus, which consists of one proton and two neutrons, can be obtained by bombarding lithium, a light metal, with neutrons. In this process, the neutrons produced by the fusion into helium in the fusion reactor can be used if the entire plasma ring is surrounded by a breeding blanket containing lithium. It must be thick enough to absorb the exceptionally fast neutrons (14 mega-electronvolts), since it will thus be possible to protect the sensitive, superconductive coils lying behind the breeding blanket. These neutrons, however, contain about 80 percent of the energy obtained from the fusion process. Consequently, the breeding blanket also constitutes the cooling system through which several thousand megawatts of power have to be drawn off. Basic research is being done at this point to find a solution to this difficult problem.

-43

There has been more progress with regard to the fuel cycle. Since deuterium and tritium constantly combust into helium in the plasma, fuel has to be fed in continuously and simultaneously helium pumped off. There are plans to set up a tritium laboratory in Karlsruhe to further develop the various stages of the process and particularly to refine the fuel-reprocessing technique. This task is not made any easier by the fact that tritium is radioactive. This radioactivity, in addition to an ever increasing gamma-ray activity inside the reactor during operation, makes it absolutely essential to develop a sophisticated technique for remote handling and control. Here too, important preliminary work is being done at the Kernforschungszentrum.

Dietrich Zimmermann

In 1982, TEXTOR was made available to international fusion researchers at the Kernforschungsanlage Jülich (Nuclear Research Centre). TEXTOR is an "experiment," i.e. an experimental plant which is particularly important for achieving concrete progress in the field of fusion technology. At this plant, which was set up solely for the purpose of investigating plasma/wall interaction, processes and methods are being developed which may determine whether the European experimental reactor, JET, will be successful:

The Flagship of the Jülich Fusion Researchers

TEXTOR stands for "Torus Experiment for Technology-Oriented Research." It involves a medium-sized fusion unit of the tokamak type, comparable in size and performance to ASDEX at the Max-Planck-Institut für Plasmaphysik (Max Planck Institute of Plasma Physics) in Garching. The ring-shaped torus, in which the plasma is enclosed, is about 3.5

metres in diameter. The torus itself has an inside width of approximately one metre.

The fact that TEXTOR belongs to the tokamak line is shown by the six five-metre-high iron yokes which span the torus (the plasma tube) from the inside to the outside. They are part of a gigantic transformer, the secondary side of which is formed by the plasma. When current is fed into the primary winding, it induces current in the plasma which the primary winding rapidly heats up. Simultaneously, the plasma current, which can presently reach a level of up to 620,000 amperes, creates a magnetic field. Together with a second magnetic field, it confines the hydrogen plasma heated to a temperature of 10 million degrees Celsius. Sixteen coils, which completely embrace the torus, create this additional magnetic field.

Despite the powerful magnetic field there is intensive plasma/wall interaction. First, plasma particles, such as nuclei and electrons, propelled by other particles, are able to overcome the magnetic-field barrier. Second, there is electromagnetic radiation. Finally, neutrons are produced in the fusion processes of future fusion reactors which convey some 80 percent of the energy obtained. These neutrons have to be completely intercepted in the final cooled-down torus jacket area of a reactor, if not at an earlier stage. This bombardment severely affects the first wall which heats up to several hundred degrees Celsius, erodes, swells, or forms gas bubbles.

Dislodged wall material may drift (as impurities) into the plasma, absorb energy and discharge it in the form of radiation. This might prevent the minimum fusion temperature of 100 million degrees from being achieved. The higher the charge level of the contaminating nucleus, the higher the radiation will be: zircon, for instance, radiates more than iron, and iron more than carbon. Consequently, efforts are also being made to coat the first wall with carbon. This technique has proved so successful in Jülich that it may be considered a genuine breakthrough.

If the torus is filled with a mixture of hydrogen and methane, TEXTOR's entire wall system can be coated with several hundred layers of carbon by using a high-frequency supported

glow discharge. With this carbonization, the contamination level has been lowered to such an exent that the length of the plasma discharge has gone up 59 percent, from 2.6 to 3.8 seconds. The carbon layer can also be removed again by using glow discharges in pure hydrogen. This, too, represents a major step forward in comparison with other methods.

The contamination, which cannot be avoided even by using optimal surfaces, the helium created during the fusion process, and the material excess hydrogen have to be removed from the torus. This is obviously best achieved with a magnetic divertor, which is being designed in Garching. However, a divertor of this kind requires complicated built-in elements which JET, the European experimental reactor (the technical planning of which began as far back as 1973), does not have at its disposal. Consequently, a pump limiter, which can also be used in JET, is being designed at Jülich. Limiters are blocks of metal or graphite which are inserted in the first wall facing the plasma. They are meant to intercept particles drifting in the plasma boundary layer which are subsequently pumped off through openings at the base of the limiter.

Since the first pump limiter, ALT-I, was highly effective as the only module, the entire torus is now to be equipped with ALT-II, its successor. The Jülich experts are cooperating with American und Japanese researchers and engineers on this project, which is being funded by EURATOM. Penetration of the fusion zone by JET will very much depend on whether the plasma/wall interaction can be controlled. This is true, among other things, because the high-frequency heating which is needed to bring the plasma to fusion temperature still has a strong impact on the boundary layer at the present state of the art. The fact that TEXTOR has been using a three-megawatt high-frequency heating system since 1984 – the result of German-Belgian teamwork – means that research may now be extended in this area as well.

Experts maintain that one of the important advances achieved by TEXTOR is that it is now possible to avoid the breakdowns in current which usually occur at the end of the

tokamak pulse and subject the plant to severe mechanical stress. In addition, the techniques for measuring plasma density and electron temperature have been improved, and the current distribution in the plasma has been measured for the first time in the world. Also, an external field perturbation coil commenced operation in the summer of 1985. It permits a swirling of the external magnetic-field configuration. It is of fundamental importance for achieving absolute control of the plasma's boundary layer and its interaction with the first wall that the interference fields and their causes and effects be studied.

TEXTOR cost roughly DM 50 million. This is not very much if one takes into consideration the fact that this experimental plant was equipped with many "extras." It was designed in such a way that one half can be moved aside to change the plasma tube quickly for material inspection, whereby "quickly" means around six weeks!

Two figures will clearly show how intensively the researchers are working: in 1983 alone, they published 103 articles on their work and applied for and received four patents.

Dietrich Zimmermann

Following a decision by the Federal Ministry of Research and Technology in late 1973 to re-activate the Heißdampfreaktor (HDR, super heated steam reactor) in Großwelzheim near Frankfurt to study safety technology, a research programme was devised unter the aegis of the Kernforschungszentrum Karlsruhe (Nuclear Research Centre). This programme calls for conducting large-scale non-nuclear experiments with genuine reactor components under conditions which are as close to reality as possible. There has never been a programme even remotely similar to the Großwelzheim study, not even in the USA:

Sparking Catastrophes in the Name of Safety

The most important objective of this programme, which is orchestrated and implemented by an international team of experts, is to prove that the basic assumptions underlying the construction of nuclear reactors in the past are reliable. Many of the components and systems of the former Heißdampfreaktor, e.g. the pressure vessel and the surrounding double-walled "containment" which completely encloses the safety container, are comparable to those in present-day light-water reactors in terms of materials and design. Hence, the findings of large-scale experiments in which earth-quakes, aeroplane crashes, or the "design basis" (the rupture of the coolant system) are simulated may be used relatively directly as a basis for monitoring and improving current construction techniques.

It goes without saying that the HDR was conceived with a totally different objective in mind. Experts originally wanted to use this experimental reactor which has a thermal capacity of 100 megawatts (comparable to an electrical output of 30 megawatts) to study the principle of nuclear superheated steam. It had been their goal to raise the efficiency of light-water reactors to the efficiency level of modern coal power stations. But when the finished reactor was slowly run up in 1969,

a fault in concept led to severe damage to the fuel elements and the plant had to be shut down in 1971.

Since light-water reactors have experienced an economic breakthrough in the meantime, a decision was made to drop the super heating concept. Investigations were subsequently undertaken to see if the HDR could be converted into a test reactor for fuel elements. But this idea was dropped for several reasons, and the road was open for reactor-safety research. The activated internal elements of the pressure vessel were dismantled between 1973 and 1975, and the reactor was converted to meet the requirements of experminental work. The most important new installation was a 4.2-megawatt electroheating system, which made it possible to heat the water in the reactor's pressure vessel to a temperature of over 300 degreees Celsius at a pressure level of 110 bars.

The HDR, located in a bend of the Main River, about 40 kilometres east of Frankfurt, is an impressive construction. The vertical, cylindrical structure, 20 metres in diameter, towers to a height of 52 metres. Its foundations go down 12 metres. The steel reactor pressure vessel, in which the fuel elements used to be located, is no less than 10 metres high; it has an inner diameter of three metres and a wall thickness of 13 centimetres. Although the pressure vessel of a reactor of the Biblis type, with an inside diameter of five metres, is more voluminous and slightly taller, the HDR experiments may be regarded as highly realistic, to say the least.

The focal point of the programme is a study of the loss-of-coolant accidents. A fracture in the pipeline is simulated with rupture discs which carry hot water back and forth between the core of the reactor and a heat exchanger or the turbines themselves. In the latest experiments at HDR, 70 cubic metres were heated to 320 degrees Celsius at 110 bars and then abruptly released through a tube with a diameter of almost half a metre. The steam which is created by this tension flows through the break nozzle at speeds of up to 500 metres per second. Within a matter of two minutes the entire reactor building, with a capacity of 11,000 cubic metres, is evenly filled with steam, and

a pressure of about three bars is created. The events following such a "blow-down," e.g. impingement forces, differences of pressure and temperature, or metal deformation, are registered by an immense number of different sensors which record the stress on the pressure tank, the reinforced concrete structures surrounding it, and the 3-centimetre-thick steel containment shell. In addition parts and components of the plant are examined by non-destructive processes following a blow-down in order to determine possible changes, such as cracks or the growth of cracks to compare the efficiency and application fields of the various testing methods.

The spectacular blow-downs, however, are but one aspect of the safety programme. The entire plant and its components, down to individual pipes, are subjected to vibratory stress using oscillators, shakers, snap-back devices and underground explosions. The researchers can thus measure the reactions to more or less comparable conditions in the case of an earthquake. In another experiment, four rocket-propelling charges were ignited which exerted a pressure of 40 tons on a small area of the outer containment shell within a period of half a second. This experiment was supposed to simulate the possible effects of a plane crash. Further important items of the programme include investigating temperature shocks and elaborating conclusive leak tests.

The HDR project, which has already cost more than DM 100 million, has produced important findings on the actual behaviour of size-for-size systems and component parts. It was proven once again that the current design and calculation processes generally establish a generous safety margin. Furthermore, the plant has been a valuable testing facility for the further development of fittings, valves, pumps, and measuring systems. During the next few years stress is to be further increased, in some cases to the total-failure limit. It should be mentioned for the sake of completeness that after all these massive tests including more than 30 blow-downs, the major component parts of HDR may be considered to be just as safe today as they were when operations originally began.

Dietrich Zimmermann

Railway history is being made in Emsland: Transrapid 06, the most advanced magnetic levitation train (maglev) in the world for passenger transportation, has been undergoing experiments at speeds of over 300 kilometres per hour on a test track in that region since 1984:

The Railway Is Beginning to Fly

As far back as the 1930s, Hermann Kemper, the "father of the electromagnetic levitation train," conducted his first successful contactless support and guidance experiments. But it was not until the end of the 1960s that the first efforts were made to realize the concept of using electomagnetic levitation technology for a high-speed rail-guided system which is apt to close the gap between the possibilities offered by the railway and the aeroplane. Development work began when using electronics made it possible to control and regulate the magnetic levitation guidance process to ascertain that there is a constant air gap between the levitation and guidance magnets of the vehicle and the track under all operating conditions. At the start of the maglev train development in the 1970s, various systems were tested at experimental centres or similar facilities by various firms or working groups. As of a certain point, the Federal Ministry of Research and Technology (BMFT) could no longer fund more than one research programme to the necessary extent. Up to that point, there had been competition between the electrodynamic and electromagnetic levitation systems in the Federal Republic of Germany, but then preference was given to the Transrapid-EMS, using the electromagnetic support and guidance technology first developed by Krauss-Maffei and Messerschmitt-Bölkow-Blohm in 1971. After 1978, development work concentrated on the electromagnetic levitation system with long-stator propulsion, the practical application of which was successfully demonstrated by a consortium consisting of Krauss-Maffei, Messerschmitt-Bölkow-Blohm, and Thyssen-Henschel during the International Transportation Exhibition in Hamburg in 1979 with Transrapid 05.

The levitation and guidance system operates on the principle of electromagnetic levitation. In this technology, the vehicles carry electromagnets, the guideway has metal rails. The levitation magnets pull the vehicle towards the rail from underneath, while the guidance magnets on its side hold the vehicle on the track. The propulsion system operates on the principle of the long-stator linear motor. It consists of a travelling magnetic field produced in the coils which are mounted to the guideway over the entire length of track. This magnetic field produces thrust forces that move the vehicle by the levitation magnets.

A decision was made in 1978 to test the high-speed electromagnetic rail system on a large experimental site under conditions as realistic as possible. Since there seemed little chance of realizing the long-planned Donauried Testing Site, a new location had to be found. The experts eventually settled for the Emsland region between Meppen and Papenburg, or, to be precise, between Dörpen and Lathen. A test track with a total length of 31.5 kilometres is currently being constructed there parallel to the Ems Seitenkanal. It has the classical form of a high-speed closed circuit with a straight stretch and a small loop at one end, and a larger loop at the other, permitting the maglev to travel continuously at speeds of up to 400 k.p.h. The first segment of the track, which includes the large northern loop, 20.6 kilometres of guideway, and two switches, allows speeds of approx. 300 k.p.h. The guideway itself generally consists of 25-metre-long beams of pre-stressed concrete or steel, both ends of which rest on concrete supports. This provides a minimum inside height of 4.7 metres above the ground. This piece of track, including power supply plant, feeder lines, and track switches, propulsion control and regulation, the test centre at the southern end, power, test vehicles, a safety system etc., was completed by the end of 1984 and cost about DM 460 million, to be paid in full by the BMFT. This figure also includes the cost of five special vehicles needed to mount the stator bundles and coils, to process the guide rails, and to test the track. They will eventually be used for maintenance and towing services.

The prototype vehicle of Transrapid 06, which reached a speed of 355.3 k.p.h. as far back as December 1985, a new world record for magnetic levitation vehicles in its class, consists of two identical sections. It is 54 metres long, 3.7 metres wide, and 4.2 metres high. Since maglev has no propulsion units proper – the driving thrust is generated by the coils in the track – optimal use has been made of the interior space. The vehicle's inside width of 3.7 metres offers enough space to install five seats side by side. Transrapid 06 thus can sit 196 passengers. The German Federal Railway's express railcar, currently operating between Düsseldorf and Frankfurt airports, only has 160 seats despite its overall length of 110 metres. Moreover, its operational weight with 120 passengers is 248 tons. But Transrapid 06, whose 120 levitation magnets (also known as "magnetic wheels") are contained in eight frames, turns the scales at no more than 122 tons with 196 passengers on board. Although Transrapid 06 will consume more energy than conventional railway systems to reach speeds of up to 200 k.p.h., it will still use much less than passenger planes. Viewed from the overall economic angle, the maglev will probably be well able to compete with conventional rail systems because its high degree of automation reduces personnel costs, and maintenance costs for guideway and vehicles will be minimal.

The full potential of the maglev becomes clear considering that it will possibly be used on the proposed super-speed track between Las Vegas, Nevada, and Los Angeles, California. Transrapid International, a company developing and promoting the implementation of Transrapid systems world-wide (headquarters in Munich), is pursuing this project. Whereas present travelling time between the two cities by conventional railroad comes to more than seven hours, the maglev could cover this distance in just one hour and twenty-five minutes on the new track. With investment costs comparable to those for express rail construction, lower operational costs, and an increased number of passengers (if only because of improved travel comfort and shorter travelling times), the maglev is not just an interesting option for covering the vast areas in develop-

ing countries. The fact that the Japanese are developing two maglev systems should be enough of an incentive for the Federal Republic of Germany to do everything possible to maintain its leading position in the field of magnetic levitation technology.

Dietrich Zimmermann

Experts consider the high-speed train of the Deutsche Bundesbahn (German Federal Railway), the ICE, to be the most modern train of its kind in the world. At the moment, ICE stands for "Intercity Experimental," but when the ICE is scheduled to start operating on a regular basis in 1991, on new high-speed lines, this acronym will stand for "Intercity Express." It is quite possible that the ICE may prove to be the forerunner of a new generation of international fast rail services. There might even be the day when ICE will stand for "Intercity Europe".

Half the Speed of an Airplane...

The Intercity Experimental is designed for a maximum speed of 350 km/h. Ever since the first train was delivered to the Deutsche Bundesbahn in the summer of 1985, it has repeatedly proven in test runs that its operation does not provide any problems. During its official début on November 26, 1985, it travelled at a speed of 317 km/h without any difficulties on a special high-speed section of track between Gütersloh and Neubeckum, thus establishing a new German speed record for railway vehicles. It also was a new world record for vehicles with three-phase drive. A 30-kilometre section of track has been available since the fall of 1986 on the new railway line between Hannover and Würzburg. On this track, the ICE will be able to operate at test speeds far in excess of 250 km/h.

The ICE is meant to run "half the speed of an airplane and twice as fast as the automobile." The train consists of two four-

axle power cars, two demonstration coaches, and a measuring coach. Each of the power cars has an output of 4,200 kilowatts (Kw) totalling 8,400 Kw or 11,400 horsepower. The power cars are constructed as steel units. A weight-saving integral aluminium frame construction was chosen for the salon-type passenger coaches. Commercial metal was used in most cases which provides a rigid, completely self-supporting frame.

A lot of effort went into soundproofing. In order to limit the interior sound level to 65 dB(A), extensive soundproofing of the floor, the sides and the roof were necessary. Despite all constructional finesse, some three tons of soundproofing and thermal insulation had to be built into each coach. Even the windows, which, at a width of 1.8 metres and a height of 65 centimetres, provide a good view, boast of a high degree of soundproofing due to their triple layer of glass which is unprecedented internationally. They are flush and integrated into the outer surface of the car. Since the 50-cm-wide intermittent sections between the windows are also glass-covered, the unbroken line of windows along the whole length of the train on the outside creates a highly elegant impression.

In order to keep energy consumption and noise production as low as possible even at high speeds and to reduce as much as possible the stress put on the trains when they pass one another or when there are gusts of wind from the side, the problems of aerodynamic drag and aeroacoustics had to be thoroughly investigated. The power car's rounded, streamlined nose ist, on the one hand, considered to be ideal and, on the other hand, it offers ample room and visibility. It is also more advantageous to produce. The base of the vehicles is completely encased with side panels providing access for maintenance purposes. The pantographs are positioned to the leeward side of the power car's nose. Gangways between the coaches are flush with the outer skin. Since pressure waves occur primarily when two trains pass in a tunnel, the passenger and driver's coaches are pressure-proof. The aim of the running gear design was a high degree of running ease and a low degree of stress on the rails. As a result of numerous tests on the rolling

test-rig at the German Federal Railways' facilities in Munich-Freimann, the following principle was eventually adopted: each power car has two bogies with two powered wheel-sets. Their special feature is the fact that they have asynchronous motors with flexible drive and hollow brake shafts. Two-thirds of the motor block and gear box are hung from the body and one-third from the bogie frame by means of flexible, lateral pendulums. In transverse direction, the principle is that at high speeds the mass is coupled to the car body, while at low speeds it is coupled to the bogie. This is a sophisticated construction which has proven successful in frequent trial runs. The Deutsche Bundesbahn hopes that the ICE wheels will not need re-turning for the first one million kilometres; the wheels of the TGV, the French high-speed train, are currently re-turned every 200,000 kilometres (maximum).

The Intercity Experimental is powered by the latest three-phase current asynchronous traction motors. The single-phase alternating current is first taken from the overhead line by means of modern, sophisticated electronics, subsequently converted into direct current, and then into three-phase current of variable frequency and voltage. The number of revolutions of the traction motors and, consequently, the speed, are controlled by varying the frequency. The three-phase current traction motors are power units that are extremely light and need little maintenance. This provides for optimal regulation, a high tractive force when starting, high acceleration, and high speeds. As a result, they function as generators when the vehicle brakes: the kinetic energy released is transformed into electrical energy and fed back into the overhead line. In addition, because of the great stress imposed on the braking system, the ICE also has a linear eddy-current braking system as well as mechanical disc brakes. These three different brake systems are coordinated electronically. For this and all other systems requiring monitoring, the ICE has its own new type of diagnosis system which records measurement details and the functional status of all important subsystems and then feeds them into a diagnosis computer. In order to test the level of market accep-

tance carefully, the ICE passengers are offered unique new facilities. Every seat in First Class is equipped with a passenger information system, a feature which is not available at the present time in any other means of transportation. It provides passengers with both information and entertainment. Interior electronic displays show details of reserved seats, the next stop, scheduled times of arrival, services available, advertizing by the Bundesbahn and third parties. There are individual headsets for each seat and loudspeakers in each coach providing music programmes, tourist information, and announcements related to the journey. It goes without saying that the train staff can be called. Two seats in First Class are fitted with telephones and visual display information services. Last but not least, video shows are offered in the club room.

The ICE is by far the most spectacular product of the "wheel and rail" research programme which was launched in 1972. The Federal Ministry of Research and Technology has provided DM 44 million for this programme, the Deutsche Bundesbahn DM 17 million, and industry DM 16 million. At the moment, the Deutsche Bundesbahn is drawing up its final "expense sheet" for future ICE express trains which will also include the results of the present experimental programme. But time is flying. Since the first trains are scheduled to be handed over between 1989 and 1991, industry must receive orders for serial production within the next twelve months at the latest. When the trains go into regular service in 1991, there will be a high-speed rail network of 1,200 kilometres which will be extended to a final length of 3,000 kilometres by modernizing existing lines and, of course, by building new stretches of track.

Dietrich Zimmermann

63

By perfecting, of all things, the production of integrated circuits through a revolutionary process, namely X-ray lithography, research experts at the Fraunhofer-Gesellschaft der Mechanik (Fraunhofer Society of Mechanics) have opened up a completely new area of application for structures of almost microscopic dimensions:

Entering a Technical Wonderland

Micromechanics is creating structures and formations which, at least in one respect, are so small that the usual methods used in precision mechanics are no longer adequate. We are talking in terms of between one and one thousandth of a millimetre.

The material used in micromechanics is a dark-grey and hard metalloid called silicon, the processing of which has already reached an incredible degree of perfection in microelectronics. It is, so to speak, a byproduct of X-ray lithography, first developed to further reduce the size of integrated circuits. Whereas these circuits are still traced by the conventional light method onto silicon chips and then etched in, X-rays, with their much shorter wavelengths, make it possible to produce sharp images much more greatly reduced in size.

Experts at the Fraunhofer-Institut für Festkörpertechnologie (Fraunhofer Institute for Solid State Technology) in Munich were working on X-ray lithography as far back as 1977 when many researchers were still convinced that this area was quite a utopian undertaking. Following the construction of the large electron storage ring for synchrotron radiation (BESSY) in West Berlin which also produces X-rays, a research laboratory was set up in Munich to work in this field: the Department of Microstructural Technology, headed by Dr. Anton Heuberger. This department is expanding continually.

The path to micromechanics has also been opened up by the mechanical stability of silicon and an increasingly innovative engraving technique. An important trick in engraving extremely thin layers is based on the fact that it is possible to stop the penetration of the etching agent at a precisely predeter-

mined depth by doping the silicon with boron atoms. It is thus possible to "underetch." Underetching means that if a layer which has been treated with boron is very thin, the etching agent can penetrate laterally and also lay this layer bare from beneath.

With this technique it is possible to etch out for instance a large number of fine, long tongues which lie like organ pipes over a cavity some two-thousandths of a millimetre thick and two hundredths of a millimetre wide. If, with the help of the finest metallic vaporization processes, the tongues and cavity are then converted into an electrode and a counter-electrode, every tongue movement changes the charge state of this system. This process can be registered in the form of an electric signal. It offers a large variety of measurement possibilities. For example, it may be used to measure tremors and speed-ups and even to provide frequency analyses because the tongues, due to their different lengths, have different properties in terms of indicating resonances.

With tongues of modified shape, quick temperature readings or determination of air moisture are possible. Tongues with a particularly large silicon chip at their centre, which oscillates freely, are even more sophisticated and sensitive. A microvalve has even been produced: it was etched out of one piece in the form of a four-cornered cavity which has a raised surface resting on four tiny crosspieces. This surface is designed to open or close a hole in the cavity as soon as the system, because of metal evaporation or other incidents, has become accessible to electric control signals. This design can be used not only for manufacturing a fast microvalve which can be controlled efficiently, but in modified versions it can also create sound of very high frequency or receive it like a microphone and convert it into electrical oscillations.

The future of these micromechanical components, sometimes no larger than a few square millimetres, is highly promising mainly because they can be combined with the electronic components used in signal processing to form single functional units on silicon chips. The "monolithic" design is also an essen-

tial requirement for economical production of these micro-mechanical parts and for more advanced developments. The work carried out at the Fraunhofer-Institut is an example of outstanding German research in the field of new technologies.

Dietrich Zimmermann

Only by access to the latest information techniques can the numerous demands placed on modern industrial plants be fulfilled today. Despite mass production, modern factories have to react quickly and flexibly to market influences. With a unique advanced "language" for systems in a large number of computers and other innovations, German experts have made a significant breakthrough:

Factory Control by Videoplay

In monitoring and regulating large and complicated technical installations, engineers actually follow Nature's example nowadays. Our environment represents a network of manifold regulator circuits which influence one another. By the same token, experts are now integrating decentralized control circuits in the design of modern industrial plants which will replace the old adopted principle of central monitoring and control.

Increasingly fierce competition in the industrialized countries and a growing awareness of quality of life and the environment are creating a situation where demands on the technical facilities of our time are being continuously increased. On the one hand, factories have to operate as productively and trouble-free as possible, but on the other, they have to produce goods of top quality. At the same time, they have to operate as economically as possible using energy and raw materials: the environment must not be overburdened more than ever, and constructional engineers have to pay attention to the human aspect when designing work places. Although mass production

continues to be the order of the day, modern manufacturing plants must not be rigidly geared to this objective. On the contrary, they have to be highly flexible to be able to adapt more quickly to possible changes in the markets.

Getting all of these requirements under one umbrella seems very much like trying to put a square peg in a round hole. But actually it is by no means impossible to reconcile these conflicting demands. Scientists and engineers are achieving this by integrating factory equipment more and more in information technology.

Admittedly, the Europeans have to catch up a lot with the Americans and the Japanese in regard to information technology. This is clearly illustrated, among other things, by ESPRIT (European Strategic Programme of Research and Development in Information Technology), a research programme conducted by the European Community. When it comes to controlling large and complicated industrial plants with highly sophisticated information technology, German experts are in the lead. Dr. Hartwig Steusloff and Dr. Dirk Heger of the Fraunhofer-Institut für Informations- und Datenverarbeitung (Fraunhofer Institute of Information and Data Processing) in Karlsruhe have developed an information system for industrial plants. It has now reached a stage where it can be used. As far as efficiency is concerned, it is unmatched world-wide. Consequently, Dr. Heinz Riesenhuber, research minister for the Federal Republic of Germany, awarded the two researchers the Technology Transfer Prize 1984.

Even large computers are now reaching the limits of their possibilities if they have to fulfil all the control tasks of complicated technology centrally. This is the reason why engineers are designing systems with decentralized control circuits in which various parts of technical plants are coupled individually to their own microcomputer. These control circuits are also connected to each other without the help of a central computer. The information system has thus adapted itself to real-world processes which, unlike the computer programmes of a central computer, take place simultaneously and parallelly rather than

consecutively. Similarly, the decentralized, largely automated control circuits mainly operate on a parallel basis.

Steushoff and Heger developed a unique advanced computer language for "distributed" information systems of this type. Their "Multi-Computer PEARL" permits programming not only the central computer but also a number of computers can be programmed to fulfil different tasks simultaneously.

To ensure that the various microcomputers complete their control assigments at the right time, the switching time is also programmed in "Real Time Language". This purpose can be achieved only if the computers "know" what time it is at any given moment. They are equipped with clocks which operate synchronously with high precision. Via radio they receive the time signal of the most accurate German atomic clock located at the Physikalisch-Technische Bundesanstalt (Physical-Technical Federal Institute) in Braunschweig.

On the basis of this computer language, the researchers in Karlsruhe developed their RDC System (Really Distributed Control System) which was first put to use in a steel plant of the Thyssen company. The task was to control and regulate 28 low furnaces in which steel blocks were heated to a temperature of 1,200 degrees Celsius in preparation for the rolling mill. At the time, the Fraunhofer-Institut experts had to hold their own against a powerful American competitor. Their RDC system not only called for microcomputers spread over the plant, but for the first time in the industrialized world, the decentralized control circuits of a control system communicated with each other optically using a single wafer-thin glass fibre. Engineers in the central control room were no longer faced with a battery of indicator panels, levers and keyboards; they had two colour screens instead which showed all the important information, processed graphically, and with the help of a light pen permitted direct intervention in operations. This was factory control via videoplay!

The RDC system had yet another sophisticated feature which is highly appreciated by industrial experts: it tolerated errors by automatically correcting faults which can never be

completely avoided. If a fault occurred in a computer, another computer assumed its functions in addition to its own.

By now, companies like Siemens, an electrical engineering company, have acquired licences, and Thyssen, as a result of its positive experiences, has already installed three further systems. These are used, among other things, to regulate energy supplies. Steusloff and Heger may consider the latest application of their system as an outstanding success: it was installed in the new Daimler-Benz AG automobile factory in Bremen where some 4,000 workers have produced almost 400 Mercedes 190 automobiles daily since 1984. The 200,000 square metres of the three production halls outside Bremen cover an area of almost 30 soccer stadiums. Two wafer-thin glass fibres, over three kilometres long, link a ring of 30 computers in the plant with the control room.

At the German Fair in Tokyo in the spring of 1984, which was the first German industrial exhibition ever to be held in Japan, the RDC system displayed at the Federal Ministry of Research and Technology's stand attracted the attention of Japanese experts. Communication technology of similar efficiency will now be developed in Japan in the framework of two research programmes sponsored by the Japanese Ministry of Commerce and Industry (MITI).

Franz Frisch

Enzymes play a prominent part in biotechnology. These proteins, which are responsible for the metabolic process in living cells, can be used outside the cell to produce natural substances:

Amino Acids as Required

The production of these natural substances takes place in so-called bioreactors, i.e. reaction vessels in which enzymes are brought together with the substances to be transformed. The

further development of bioreactors is the subject of intensive research world-wide. It is a field in which the bioengineers at the Kernforschungsanlage Jülich (Nuclear Research Centre) may have hit the jackpot: the successful starting up of the first commercially operated membrane reactor. It was set up at the Degussa AG company in Konstanz and produces some 200 tons of L-amino acid annually.

These amino acids, e.g. methionine and valine, are the basic components of all proteins. Whereas plants and most micro-organisms can produce the amino acids they need themselves, humans and domestic animals such as pigs and poultry cannot. Their cells can only produce some amino acids on their own. The missing components consequently have to be absorbed as vegetable and animal proteins.

Useful plants, however, do not contain amino-acids in the precise composition which humans and animals need. Therefore, even carefully processed food mixtures require certain amino acid additives, such as methionine and lysine. Although these two amino acids, like most others, can be synthetized chemically, there is one basic problem: amino acids are structured in such a way that they can occur in two axial-symmetric forms, i.e. the D and the L-forms, which differ from each other like the right hand differs from the left. In the case of chemical synthesis, both forms occur with the same frequency; however, organisms use the L-form almost without exception. In other words, only half of the manufactured amino acids are used. The other half, the D-form, is usually nothing more than useless ballast.

By contrast, biosynthesis of amino acids in living organisms takes place stereospecifically: only the L-form is produced. The experts have taken advantage of this fact. They use isolated enzymes for the transformation in their bioreactors. The enzymes are taken from micro-organisms or specific tissues, e.g. pig kidney tissue. If suitable substance is added, they convert it into L-amino acid.

Enzymes are expensive and sensitive. In order to avoid their being washed away with the manufacturing solution, they are

combined with a carrier material. This, however, reduces their activity, since the primary product must first penetrate the carrier material before it reaches the enzyme. Furthermore, since the lifespan of an enzyme is limited, the entire enzyme filling has to be changed after a certain time, which means that the enzymes which are still active will also get lost.

An enzyme membrane reactor was designed in Jülich to avoid these disadvantages. It takes advantage of the fact that enzymes, long-threaded, convoluted structures, are considerably larger than the amino acids, the product molecules. If the outlet side of the reactor is closed with an ultrafiltration membrane, it is thus possible to keep the large enzymes back in the reactor while the small amino acids can be discharged through the fine pores, which are just a few millionths of a millimetre in size.

These membranes make the dream of every biotechnologist, namely a continuous production process, come true. The enzymes and the substrate are channeled through the bioreactor in a constant cycle. The reactor consists of a bundle of hollow fibres several millimetres thick. The substrate enzymes flow through the hollow fibre which consists of an ultrafiltration membrane. The product and part of the substrate are drained off.

The amino acids manufactured in membrane reactors are so clean and sterile that they can be used without any further treatment in both foodstuffs and the pharmacological field.

Dietrich Zimmermann

For the first time, the fairly accurate knowledge concerning the origin of hydrocarbons (oil and gas) and their accumulation in deposits has been reduced to calculable form. A process which actually takes millions of years can now be recreated via computer at the Institut für Erdöl und Organische Geochemie (Institute of Petroleum and Organic Geochemistry) at the Kernforschungsanlage Jülich (Nuclear Research Centre):

How Oil Matures in the Computer

Wherever mineral substances are deposited together with plant and animal remains in water-filled depressions, oil and gas can be created through microbial and geochemical processes. However, large deposits which can be exploited economically will occur only if the organic materials are rapidly covered in such a way that they are protected from oxygen.

These kinds of depressions, in which "rapid" geological processes take place, are found all over the world in the form of "sediment basins". For years attempts have been made to record quantitatively the transformation of the organic substances into oil and gas and to trace their migratory movements in order to make a reliable assessment of the volume of the deposit in each case. The step now taken by the experts in Jülich to create a complete computational model is the logical realization of a world-wide trend in research.

Fine-grained clays or lime mud and coarse-grained sand accumulate simultaneously or consecutively in typical sediment basins of this type, whereby the organic substance is only preserved in the fine-grained sediments. The porous sand which later hardens into sandstone provides a reservoir for the oil and gas which gradually mature in the fine-grained bedrock. The latter must contain at least a half to one percent of organically bound carbon if the oil is to occur in commercially viable quantities at a later date.

The organic substance matures in the source rock, subjected to the influence of heat, time and pressure, whereby the fatty,

protein, carbo-hydrate and other substances are heavily "standardized" and some of the carbon chains changed into ring molecules. In this way, the oil parent substance kerogen is formed, from which the individual oil components are subsequently split off. According to present knowledge the maturation process can take 100 or more million years. If the earth's heat is very high, five to ten million years might suffice. What is important is that it is also possible to measure the maturity level of the mineral oil.

Following a number of processes, some of which have not yet been fully clarified, oil and gas start to migrate during or after their maturation from the source rock and form reservoirs provided that they happen to flow into a "trap" of reservoir rock which is sealed off at its upper surface. These traps are usually predetermined by the local structure of rock layers, such as arching or displacements of the earth's crust which provide the reservoir rock with an impermeable cover. These irregular features, generally known as "structures", are the basic targets of oil prospecting, provided it has been established that there is sufficient oil available in a basin.

The development of a sediment basin, which may cover thousands or hundreds of thousands of square kilometres and the deposits of which may have a thickness of up to ten kilometres, can be reproduced in a computer as long as certain basic data has been gathered in drilling and surface investigations. The experts must know the depth of the basin, the productive level of the oil source rocks, the volume of organic substance, the extent of the oil maturation, which geological processes have had an influence, and where reservoir rock and "trap structures" may be expected.

These geological, geochemical, thermodynamic, and hydrodynamic data form the basis of a sediment-basin model. This model consists of a three-dimensional grid system of points, for which data is available concerning just a small section, and for which data must be carefully estimated for the others. The grid system makes it possible to simulate the processes in sediment basins from their inception up to the present day. One simu-

lation run requires about an hour's calculating time, which means that millions of years of "real time" can be reduced to minutes.

Obviously, the first simulation run never, or rarely ever, shows results which coincide exactly with the present conditions. For this reason, the input data has to be repeatedly modified by changing the estimated data and parts of the model to the point where the results of the simulation run coincide with the results measured in the sediment basin itself.

As soon as the computer calculations, following numerous optimization steps, have been successful, it may be presumed that the calculated developments in the sediment basin also apply to places for which no data is available. Consequently, the anticipated volume of oil and gas and the location of the substances within the basin and reservoir rock can be established without having to resort to further costly exploratory drilling. Further prospecting can be managed much more efficiently. The basin models already calculated provide about one computation point per 20 to 50 square kilometres for a total (typical) area of 25,000 square kilometres. The geological and geochemical data in the computer programme, such as locally varying degrees of maturation of the oil source rock, can be plotted on maps. Work is being done at the moment to adapt the programme to more complicated geological circumstances.

In order to exploit this new technique, the Kernforschungsanlage Jülich has set up a commercial company, Integrated Exploration Systems (IES), which can improve the success ratio in exploration by making more accurate predictions as to the location and size of oil and natural gas deposits.

Dr. Harald Steinert

Although several German geologists didn't find what they had expected under the hot sands of the Kalahari Desert, they eventually did obtain verification of what they had set out to do on their search. They were working on a decisive test and further improvements in regard to a detection method which has made the Bundesanstalt für Geowissenschaften und Rohstoffe (Federal Institute of Geosciences and Natural Resources) in Hannover the world-leader in this field:

Geochemistry Helps in the Search for Ore

In prospecting for deep-lying or hidden deposits, conventional geophysical methods are not always adequate because many types of ore cannot be detected through changes in the local gravitational field or disturbances in the earth's electric or magnetic fields. This represents a challenge for geochemistry. The methods of this discipline make it possible to assume the presence of possible resources based on the amount of specific surface substance enrichment. Great success has thus been achieved, for example in the exploration of Irish non-ferrous metal deposits.

If ore deposits of this kind are covered by young, loose rock, however, the geochemical method frequently becomes so problematic that success may be a matter of pure luck. But modern prospecting cannot rely on chance. Therefore, high hopes are being pinned to new gas-geochemical techniques which are used to find characteristic gases emanating from concealed deposits, and which neither desert sands nor similar screening substances can keep in check. Although in principle these gases exist everywhere, their presence has to be more marked above ore deposits than elsewhere.

One of these gases, which is supposed to be typical, is mercury vapour found in widely differing types of ore deposits. While an increased discharge of helium from the earth does not necessarily indicate the existence of ore (except in the case of

uranium), it does suggest that there are subterranean fissures and cracks which are likely to show interesting features. Experts from the Bundesanstalt für Geowissenschaften und Rohstoffe previously tested the effectiveness of the helium method in parts of the USA with known uranium deposits, tectonically affected areas (for earthquake research), and wherever deposits are tied to tectonic disturbances.

In addition, a highly promising technique has now been developed in Hannover which permits the detection of sulphide ores through escaping sulphurous gases. This verification is very important because most non-ferrous metals, as well as silver and mercury, consist of sulphur compounds. If these ores come into contact with ground water, i.e. if they oxydize, gases such as carbon bisulphide or carbonyl sulphide evaporate. Some of these gases can be detected, and all of them can be accurately measured using gas chromatography.

This ore-prospecting technique is by no means new: in the Soviet Union, for instance, dogs have been trained to smell sulphur gases for the last decade. Some years ago, a Swedish firm sought to detect sulphur gases above the Baltic Sea waves in the Gulf of Finland which might indicate a possible extension of ore lodes. At the Bundesanstalt für Geowissenschaften und Rohstoffe this method has been refined to such a degree that it reacts to the tiniest trace of gas emanating from deep-lying ore deposits. Concentrations of one milligramme per ton of rock have to be registered in order to achieve this reaction.

In first tentative tests, this method was used above known German ore deposits and produced such favourable results that further experiments were conducted above ore deposits under the desert sands of Arizona and Namibia. The technique was then officially used for the first time in Botswana in 1981 as part of an ore-prospecting project promoted by the Federal Republic of Germany's programme of technical cooperation. To this end, more than 5,000 gas samples were taken, generally some 50 metres apart, from suitable areas with a relatively flat, sandy surface and then analyzed. Although they showed local sulphur gas enrichment, it turned out in the course of this pro-

ject, which was concluded in 1984, that these sulphur gases did not emanate from ore veins: they are attributable to microbiological processes.

This result, however, has by no means disproved the usefulness of the method. On the contrary, it is an important gain. Today, the procedure, in its markedly improved form, distinguishes reliably between these two different types of sulphur-gas sources, and has already been tested in several case studies in Botswana and the Federal Republic of Germany.

Dr. Harald Steinert

At its top it will be between 70 and 80 centimetres in diameter, but at its bottom it will be no more than 20 centimetres. In between there is something spectacular which is equivalent to the distance between the cities of Bonn and Brühl: Germany's giant hole will reach a depth of some 14 kilometres six to seven years after drilling first begins in 1988:

Germany Will Get a Giant Hole

This basic research project will provide German geology, held in high regard internationally, with a unique glimpse into the secrets of the earth's upper crust. It represents an enormous technical challenge and will cost some DM 450 million. The go-ahead for this project was given in 1985 by Bundesforschungsminister (Federal Research Minister) Dr. Heinz Riesenhuber, who adopted the recommendations of a commitee of experts from his ministry and the Deutsche Forschungsgemeinschaft, DFG (German Research Association). Under the direction of the DFG a detailed study for this "Continental Deep Drilling Programme" by the Federal Republic of Germany was drawn up as far back as 1981.

In 1982, the Bundesministerium für Forschung und Technologie (Federal Ministry of Research and Technology) started financing a large number of carefully prepared prelimi-

nary studies. In 1983, the judgment of a DFG team of international experts provided the basis for the positive final decision. The Niedersächsisches Landesamt für Bodenforschung (Office of Geological Research of the State of Lower Saxony) in Hannover has been put in charge of the project which will be accompanied scientifically by a new DFG programme to promote critical research. Preliminary technical investigations by the Kavernen-Bau und Betriebs-GmbH, a Preussag-Salzgitter subsidiary, have already confirmed the feasibility of this venture.

Just where the earth will be penetrated to this enormous depth was finally decided in the fall of 1986, after some 200 geologists had reduced the 40 possible sites to a short list of two: the Schwarzwald (Black Forest) near Hornberg and the Oberpfalz (Upper Palatinate in Bavaria) near Erbendorf. Eventually, Erbendorf was selected as the site for the drilling for technical reasons. Basically, it was a matter of finding the most interesting site geologically and determining where the lithological layers, which lie at a lower level elsewhere, are particularly easy to reach.

The primary objective of this German drilling project differs considerably from a similar Soviet venture on the Kola Peninsula. This drilling has now reached a depth of more than 12,000 metres, even though it was done for the most part in a gigantic block of crustal rock over one thousand million years old and is placed outside of what geologists call the Central European Stress Field.

The German reseachers' main interest in studying an earth which has moved and is mobile to a surprizing degree in time with geological "clocks" is centred on such stress fields of tension. Alfred Wegener (1880-1930) was one of the first to establish this changing face of our globe and the first to explain continental drift. Today, his theories, assembled under the term "plate tectonics", have been largely substantiated and show the dynamic picture of the Blue Planet which, first and foremost, constantly splits along mid-oceanic ridges, creating a new seabed out of molten magma. The old seabed is displaced and dis-

appears under the continental periphery where it melts. Like a gigantic motor, this process has been shuffling the plates of the rocky scale surface of the earth, which bear both the land and water masses, like a jigsaw puzzle for millions of years. The disintegration of each structure means the genesis of a new one.

But movements of all kinds are not restricted to large surface areas. There are displacement and circulations of material in the crustal parts. Their existence, which was discovered recently, is not only fascinating from a scientific angle; in the quest of further information they also show how material deposits emerge and where others, still unknown and deep-lying, may be explored with every chance of success. Furthermore, research conducted in this manner can contribute to a better understanding of the activity of these gigantic earth forces which may either act as slowly as a vice or suddenly "break under the strain" with castastrophic speed, resulting in such phenomena as earthquakes or volcanic eruptions.

Europe is particularly interesting from this point of view since it has been in the stress field of tension of the North American, African und Asiatic continental plates for some 600 million years. North America and Greenland formed Europe's west coast at that time; in the south the African continent forced its way northwards, and the Asiatic plate in the east. This field of tension left behind a unique diversity of geological structures in a very small region: intensely folded rock formations, lying partly above each other in some cases in the German Mittelgebirge, deep and steep rift valleys such as the Oberrheintalgraben, and large low-lying areas in the north of Germany.

The question of how it was possible for solid and brittle rock such as granite to be so intensively "shifted" in this gigantic earth-displacement game is just as intriguing to reseachers as are the questions regarding the physical and chemical processes which were active then and are still active now, regarding the origin of the forces which created mountains, and the causes of the earthquakes which are as dangerous as they were in the

past. Many of the anticipated answers will be found with the help of this enormous bore hole into the depths where the drilling cores will be able to confirm or refute indisputably theoretical assumptions or indirect measurements gathered in the past. It goes without saying that the bore hole will also provide a point of departure for further indirect investigations which will be carried out by measuring instruments located in the depths. In concrete terms, this project is concerned with the registration of the special features of the earth's crust, the seismic exploration of its conductive properties for artificially triggered tremor sound, its electric and magnetic properties, its former and present physical and chemical state, and the circulations of material which have occurred. Thus, further information will be obtained on the tensions in the earth's interior and consequently on the origin of earthquakes. In general terms, of course, the project is to obtain as complete a picture as possible of the earth's geological structure and changes in the interest of the search for raw material deposits.

For the first time, virgin territory will be explored in Germany's depths during the next few years. As is the case with any scientific advance into the unknown, the cost-effectiveness of the project is very much dependent upon how reasonably the anticipated and unexpected results will be used. We may expect that science will be ready to deal with the risks involved. But we may also be sure of something else, namely that this project will give German geology research on the earth's crust an internationally leading position.

Rolf H. Simen

More than fifty years ago the USA initiated radio astronomy, which then experienced a major upswing after World War II. This stems in no small degree from the substantial contributions made by German scientists who were first allowed to resume work in this field, using parabolic antennae, in 1955. They obtained important results from their research with the 100-metre telescope near Bad Münstereifel-Effelsberg in the Eifel. It commenced operations in 1972 and is the largest fully steerable radio telescope in the world:

The Other Face of the Universe

Unlike most other areas of this scientific field, the date of birth of radio astronomy can be stated fairly accurately. In 1932/33 Carl Guthe Jansky, a radio engineer at Bell Telephone Laboratories in New Jersey, USA, examined atmospheric interference in the 15-metre shortwave frequency band which was of particular interest for long-distance radio communication at that time. He discovered interference radiation, the maximum strength of which shifted by four minutes daily. This corresponded exactly to the difference between sidereal and solar time, which suggested that the source of this radiation was to be found outside the solar system.

Although Jansky succeeded in establishing the direction of this cosmic radio emission, known today as diffuse galactic synchrotron radiation, his discovery sank into oblivion until amateur astronomer Grote Reber built his own radio telescope. Using this antenna, equipped with a parabolic reflector 10 metres in diameter, he began extensive investigations in 1936, confirmed Jansky's discovery in 1939, and published the first radio map of the Milky Way in 1944. During World War II, Kurt Fränz and other staff members of the development section of the Telefunken company began investigating radio emission for the first time in Germany. Among other things, they observed galactic radio radiation at a wavelength of ten metres. A report on their findings was published in 1943.

Even though radio astronomy using parabolic antennae was

forbidden for German researchers until 1955 because of its close association with arms development, a major German research contribution was made at this time. Professor Peter G. Mezger, director of the Max-Planck-Institut für Radioastronomie (Max Planck Institute of Radio Astronomy) in Bonn, which was founded in 1966, recalls: "The German Wehrmacht had left behind about 1,500 radar antennae in all the parts of Europe which it had previously occupied. They were of the Würzburg Riese (Würzburg Giant) type and had been produced by the Zeppelin company in Friedrichshafen out of punched aluminium sheeting 7.5 metres in diameter. Wherever radio astronomy groups were established in Europe (in Britain and the Netherlands, for example), the Würzburg Riese was always on hand".

In 1956, a radio telescope 25 metres in diameter was erected on the Stockert Mountain in the Eifel, 40 kilometres west of Bonn. It was operated by Bonn Univerity. In contrast to optical astronomy, radio astronomy investigates interstellar matter, gas and dust clouds, i.e. things not generally accessible to optical investigation methods.

Such clouds of interstellar dust are located, for instance, at the centre of the Milky Way. The dust absorbs the visible light so that exploration using optical astronomy can make very little progress. Radio waves, however, are in no way obstructed by interstellar dust and reach radio astronomers' earth-bound instruments on a wavelength extending from about 15 metres down to 0,35 millimetres, i.e. via a "window" which is limited on the longwave side by the ionosphere and on the shortwave side by the water vapour and oxygen molecules in the atmosphere.

The so-called continuum radiation which consists of two components predominates down to the centimetre waves. The one component is thermal "Bremsstrahlung", i.e. radiation due to moderated particles, which occurs when interstellar matter, heated up and ionized by hot stars, moderates electrons in the electric field of its ions. The other component is synchrotron radiation which, as a general rule, makes a larger contri-

bution to continuum radiation. Synchrotron radiation is generated by the electrons located between the stars. Through a process which has still not been fully understood, these electrons are accelerated almost to the speed of light. This type of radiation was first discovered in synchrotrons, i.e. electron accelerators.

The smallest angular distance at which two objects can still be reflected by the telescope as two separate sources is important for radio astronomy. This angular distance becomes smaller if the diameter of the telescope gets bigger or the wavelength of the radiation used for observation purposes gets shorter. Shortly after the foundation of the Max-Planck-Institut für Radioastronomie the 100-metre radio telescope near Bad Münstereifel-Effelsberg, which the Stiftung Volkswagenwerk (Volkswagen Foundation) funded with DM 29 million, began operating at full capacity. Although it was originaly designed for centimetre radiation, it can be used as a matter of routine today down to the shortest wavelength of seven millimetres because of its exceptional surface accuracy and the new constructional concept of "homologous deformation".

Because massive and hot stars can also excite the gas and dust clouds surrounding them to radiate in the infrared and heat emission areas, radio and infrared astronomy have for the very first time made it possible for experts to look inside the dense gas clouds where stars originate. Consequently, the processes leading to the compression of interstellar matter into new stars can be better understood. Like the sun, the stars combust their hydrogen helium and even heavier elements. In their final stages of development they then return the bulk of their mass to the interstellar matter. Radio and infrared astronomy have been able to make major contributions to this picture of a constantly developing cosmos.

Through intensive collaboration between radio and optical astronomers, new and intense radiation-emitting objects (quasars) were discovered. Their illuminating power is a thousand times greater than that of our Milky Way. These distant galaxies are being observed at a stage of development

which roughly corresponds to 10 percent of the current age of the universe. In this connection research is centred on the mechanism which leads to the emission of radio-radiation. To this end, the scientists in Bonn are jointly evaluating the data collected during observations on several continents.

As early as 1981, the Max-Planck-Institut für Radioastronomie published the currently most precise radio map of the whole sky, showing our galactic environment in the "light" of a frequency of 408 million Hertz or a wavelength of 73 centimetres. Some 20 million measured values were obtained for this purpose over a period of 15 years with the radio telescopes in Jodrell Bank (Great Britain), Parkes (Australia), and Bad Münstereifel-Effelsberg. These values were tabulated in a computer programme developed by the astronomers in Bonn for automatic image processing, resulting in the first automatically reproduced radio map in the world. It consists of 160 individual sheets which cover the whole sky in sections of 20 x 30 degrees.

Celestial maps have now become a tradition in Bonn which not only applies to radio astronomers. Whenever astronomers want to find stars again using a telescope, they reach for the "Bonner Durchmusterung" (Bonn Survey). As far back as 100 years ago, Friedrich Wilhelm Argelander painstakingly registered all shining objects in the sky. The lithographic blocks, carved stone plates, for this stellar atlas can still be admired at Bonn University.

Radio astronomers are continuing this tradition. Some 30 years ago, Professor Wolfang Priester and Dr. Franz Dröge completed their sky survey, which they had begun at Kiel University, in the 200 MHz cosmic radiation range in Bonn. It took the experts three whole years at that time to reduce the 10,000 observation values obtained in the Federal Republic of Germany and Australia, in order to draw up the first radio map of the entire sky by using a 25-square-metre dipole antenna. Electronic data processing was still in its infancy in those days.

The second sky map was brought to Bonn by Professor Richard Wielebinski when he moved from Sydney to the Max-

Planck-Institut. It shows even greater detail because the most efficient radio telescope (64 metres in diameter) in the southern hemisphere was used, namely the telescope in Parkes, Australia. This antenna also covered the southern part of the new 408 MHz all-sky map. These projects as well as a scan of the northern radio sky in the 21-centimetre range by the radio telescope on the Stockert which was completed years ago are of a long-term nature. Scientists are convinced that "the painstaking process of scanning the skies will produce valuable scientific capital".

Scientific gains of this kind are also expected from the new 30-metre telescope on the Pico Veleta (3000 metres) in the Sierra Nevada, southern Spain. However, this telescope is used for individual observations rather than for surveying projects. The Bonn researchers developed it for the Franco-German Institute of Radio Astronomy. Signals down to one millimetre of wavelength can be measured. Thus, this telescope will open up a new area of radio astronomy, as will a 10-metre telescope for the sub-millimetre wavelength range, which is already under construction.

Uwe Kopacz/Eugen Hintsches

The Deutsch-Spanisches Astronomisches Zentrum (German-Spanish Astronomical Centre) on the 2,160-metre-high Calar Alto in the Sierra de los Filabres near Almeria in southern Spain has been fully equipped since the Fall of 1984. Its main instrument, a mirror 3.5 metres in diameter, is the first large telescope in the world which can be used without limitations for observations in the area of infrared heat radiation, thus opening up completely new dimensions for astronomy:

A Closer Look at the Stellar Nursery

The Andalusian observatory might be called the "field station" of the Max-Planck-Institut für Astronomie (Max Planck Institute of Astronomy) in Heidelberg, which was established in 1969. Construction work on the observatory began in 1973, and later that year the Schott glass production company in Mainz began casting a mirror for this large telescope using zerodur, a glass-ceramic material developed by Schott. Zerodur is a material whose sensitivity to temperature is so minute that it can hardly be measured. At a temperature variation of 10 degrees Celsius, the 3.5-metre mirror changes its size by no more than one thousandth of a millimetre. This huge telescope is the highlight of a large number of instruments on Calar Alto.

These instruments include a telescope with a mirror diameter of 1.23 metres and another with a mirror 2.2 metres in diameter. Like the largest instrument, these two telescopes were constructed by the Carl Zeiss company in Oberkochen. Furthermore, there are an 80-centimetre Schmidt mirror for large-scale sky photography, which has its optical "origins" in the observatory in Hamburg-Bergedorf, and a 1.5-metre reflecting telescope which was built by the Spanish Instituto Geográfico for the observatory in Madrid.

Even the gleaming white buildings housing these instruments are highly impressive. The new giant is located in a domed structure 43 metres high: the revolving upper section is no less

than 1.35 metres in diameter. The telescope itself is 22 metres high; its revolving rotor and barrel turn the scales at 230 tons. The overall weight of the computer-controlled equipment comes to 430 tons. Three different optical systems above the main reflector can be automatically exchanged very quickly. The precision of this instrument is best illustrated by the fact that two lit candles placed 150 metres apart at a distance ot 30,000 kilometres can be made out as two separate sources of weak light.

The first instrument on Calar Alto was the 1.23-metre telescope loaned by the Deutsche Forschungsgemeinschaft (German Research Association). It has been in operation since 1975 and was a magnificent present to the Spaniards in 1976. Using this telescope and a secondary infrared facility, a new Milky Way system was discovered and named "Calar Alto 1." Another result of this kind of infrared astronomy was that this new way of exploring the cosmos became generally known. It now determines several focal points of research on Calar Alto and has given "old-fashioned" optical astronomy a remarkably modern look again. What was invisible in the past is no longer invisible.

The course being followed in the exploration of the universe has been outlined by Professor Hans Elsässer, the managing director of the Heidelberg Max-Planck-Institut who points to the example of the young "newly born" stars which still lie concealed in their mother clouds and are therefore detectable only with infrared. Right from the start, the experts on Calar Alto have been on the track of their cool origin in these dense dust clouds, impenetrable by visible light. Elsässer's best example for this research is object S 106 in which the disc-shaped mother cloud surrounding the young star is viewed from the side and perforated in both polar regions. The star's radiation through these two holes causes the enveloping gas to shine. This is why such formations are known as "bipolar nebulae."

With high-efficiency auxiliary equipment, the astronomers have succeeded in tracking and recording the movement of the gas enveloping these objects with unprecedented precision. It

turned out that the young star's nebulae are literally blown outwards. One stage in the birth of a star was thus discovered which suggests that new stars are active for a short time, a fact which has been unknown so far. Observations of other objects of this type have shown that these directional currents always emanate from a stellar centre which is located in the flat disc at right angles to the direction of flow. According to Elsässer, these dust discs are extremely fascinating because, among other things, they "could be the preliminary stage of a planetary system." A large number of these new or burgeoning stars have been discovered on Calar Alto. They eject jets at speeds of several hundreds of kilometres per second most likely in the initial phase of their mother-cloud-penetrating activity.

The new 3.5-metre telescope will not only be able to provide more information on these phenomena, but will also undoubtedly help clarify those mysterious processes in active radio galaxies and quasi-stellar radio sources (quasars), whose external picture somehow resembles the exciting new observations in the stellar "nurseries." At the same time, the astronomers are looking back into the past of the universe since a galaxy 10,000 million light years away offers the same picture today as it did when the solar system, which is "only" 4,600 million years old, did not even exist.

Jets have also been discovered in these stellar systems which, according to Elsässer, are energy-packed, sharp barbs of matter ejected by active cores. This also applies to quasars which, according to research results achieved with the 2.2-metre telescope on Calar Alto, can no longer be regarded as round, more or less punctiform objects. Rather, weak coronae suggest that they may actually be the active cores of "relatively normal" stellar systems. As far as observations of the jets are concerned, considerable progress has been made recently with this telescope in regard to the brightest quasar, 3C 273. "Parallels to the jets are beginning to emerge," Elsässer comments. "A mutual enrichment in the studies of such heterogeneous objects may well be forthcoming." It will therefore be exciting to see the new gateway to knowledge opened by this new and very large instrument. *Rolf H. Simen*

The dedication of the two European observatories on the islands of Tenerife and San Miguel de La Palma in late June 1985 was an important event for German research: the beginning of research work with the two new German solar telescopes in Tenerife, which are part of a major joint scientific programme, will provide solar physics with strong new impulses world-wide:

Solar Research on a Volcanic Island

The final choice of the Canary Islands came after years of extensive tests which also included the Mediterranean. These tests clearly showed that the atmospheric conditions prevailing over this archipelago, located west of Africa, are the best: very clean air and very stable weather. Thus, researchers can rely on having a relatively large number of days and nights for observation purposes. Swedish researchers made a start in 1980 by erecting a solar and a stellar telescope on the Roque de los Muchachos, La Palma's highest mountain. The Danes and the British, whose equipment was dedicated jointly with that of the Swedish researchers in La Palma, followed suit by setting up further stellar telescopes, since the nocturnal scattered light from the inhabited area is considerably weaker than in Tenerife.

As the Germans only wanted to research in solar physics, they chose the elevated plateau of La Izaña in Tenerife, a site near the central Pico de Teide (3,317 metres) where the Spaniards and the Germans were already jointly operating small solar telescopes. Measurements had shown that the number of sunny days – more than 250 annually – is greater there than in La Palma; the fine Sahara dust occasionally blown across from Africa is of relatively little significance. Like the observatory in La Palma, the Observatorio del Teide is located at an elevation of 2,400 metres. Since both islands lie in the path of the North-East trade wind and the corresponding anti-trade wind, an inversion layer often forms at an altitude of 1,500 to 1,900 metres. This layer consists of an evenly distri-

83

buted, dense cloud pall which prevents the turbulent air warmed by the earth from rising. As a rule, a strong north to northwest wind blows above this layer. This is of utmost importance for the operation of the solar telescopes since it disperses the hot air which would disturb the optical image, thus making sharp solar pictures for lengthy periods possible.

The construction of the two solar towers began in 1983. The telescope belonging to the experimental solar physicists from Göttingen University Observatory was installed in the smaller tower, some 20 metres high. It is a Vacuum Gregory Telescope (VGT), which had already been successfully used at an outstation near Locarno, Switzerland, since 1960. In the late 1970s, however, the increasing pollution of the air and the growing demands on the resolving power of solar telescopes prompted the decision to have the equipment thoroughly overhauled, including the fitting of electronic data processing systems, and to change the location.

While the Vacuum Gregory Telescope went into operation in late 1985, the second one, a Vacuum Turret Telescope (VTT) belonging to the Kiepenheuer Institute of Solar Physics, Freiburg, has yet to be installed in the 38-metre-high tower, which is still under construction. It is expected to begin operating in 1986. The Freiburg experts also had an outstation for many years, namely on the Isle of Capri. The telescope to be used in Tenerife, however, is of a completely new design and financed with grants totalling DM 5 million by the state of Baden-Württemberg.

What is so fascinating about the sun to scientists, justifying such high expenses? The building of the two towers alone, financed by the Deutsche Forschungsgemeinschaft, DFG (German Research Association), will cost some DM 20 million. Paradoxically, the sun is just an average G1 type dwarf star, one of 100 billion (10^{11}), similar stars existing in our galaxy alone. But it is the only one close enough to the earth that it can be studied more or less with a magnifying glass.

Physicists describe the sun as a gigantic plasma-physical laboratory which permits the observation of nuclear fusion pro-

cesses, flows of energy and matter, and the interaction of magnetic fields and solar plasma, provided they give off electromagnetic radiation or influence the radiation emitted by other layers or processes. Today, solar physics means, first and foremost, taking pictures of the upper solar layers in the visible-light area with as much resolution as possible, localizing them precisely, registering changes in the recording structures and, with the aid of spectral analyses, tracking down the causes of these structures and their changes. Solar physics has often been a trailblazer, when it was a matter of transferring physical laws to cosmic matter. The theories on the structure of stellar atmospheres, cosmic element frequency or the concepts of stellar chromospheres, stella coronae and stellar winds, all originated in solar physics or had their first "baptism of fire" when applied to the sun.

The two Tenerife telescopes differ in design. The VGT, a reflecting telescope with an aperture of 45 centimetres and a focal length of 25 metres, tracks the sun. The beam is then deflected in the axis in such a way that all ancillary instruments, e.g. the spectrograph, can be permanent fixtures. The VTT, on the other hand, is a classical turret telescope. In other words, the sunlight is directed through a mirror system into a vertical tube (2.5 metres in diameter and with an aperture of 60 centimetres) which is installed in the turret. Since the main mirror at the bottom of the highly evacuated tube has a focal length of 46 metres, the beam has to be "folded" once more by means of a surface mirror before it can be guided into the spectrograph or horizontally into three laboratories. This spectrograph goes down a maximum of 16 metres below the surface.

Both telescopes complement each other in their observation properties. Consequently, there are plans to intensify joint observation projects which will include the Swedish solar telescope in La Palma, a future French telescope, American stations, and even the telescopes installed in spacecraft such as Space Shuttle. Whatever the case may be, it looks very much as if the Observatorio del Teide will soon be playing an important role in the field of solar research.

Incidentally, all astronomic facilities in La Palma and Tenerife are located on sites belonging to the Instituto de Astrofísicas de Canarias (IAC). All observation installations are assigned to the Institute. Rights of use were set out in international agreements with the Kingdom of Spain which is thus making major infrastructural contributions to these projects.

Dietrich Zimmermann

In a move to preserve and explore those areas of Carthage which have not yet been built over, ten nations, including the Federal Republic of Germany, have joined forces in an unusual large-scale rescue operation. The campaign was launched as the result of an appeal by UNESCO. Professor Friedrich Rakob of the Deutsches Archäologisches Institut in Rome (German Archaeological Institute) has been in charge of German excavations since 1975. His project is designed to clarify unsolved questions regarding the history of this ancient metropolis in Punic and Early Roman times:

Carthage Rises from the Ashes

The German archaeologists staked out their excavation site, an area of some 8,000 square metres amidst gardens and modern villas, close to the sea in the Bay of Carthage. It seemed likely that this location would provide them an opportunity to dig down to the Punic layers which they hoped to find beneath the anticipated traces of Roman foundations. This self-imposed objective was realized: for the very first time, the remains of the oldest settlement, original Carthage, were identified. They were dated back to the 8th century BC about which little is known today, proving that the assumed legendary date of foundation, i.e. 814 BC, as given by ancient historians such as Timaeus, a Sicilian-Greek, or Appian, an Egyptian-Roman, is not quite so legendary after all.

According to tradition, Dido and her followers from Tyre ceremoniously founded "Kart-Hadasht" (Carthage), i.e. "New Capital," in the well-protected Gulf of Tunis. Their plans called for more than just a port of call or anchorage for merchants on their long voyage to the silver mines in Southern Spain. The settlement was the beginning of a city which was to develop into a rich trading metropolis over the centuries. With its own fleet, it was to dominante the entire market in the Mediterranean through the exchange of raw materials and finished goods, and eventually, it was to become Rome's rival.

There are certain expectations and criteria which may be attached to the exploration and excavation of the numerous well-preserved Roman cities in North Africa, such as Leptis Magna, Dougga or Volubilis. However, these expectations and criteria do not apply to Punic remains. The Roman cities died slowly, and were eventually abandoned and enveloped by drifting sand. Hannibal's Carthage is a very different matter: in accordance with the classic demand "Ceterum censeo Carthaginem esse delendam" by Cato, the Roman senator, the city was deliberately levelled for political reasons by the Roman conquerors in the Punic Wars that lasted three generations.

Not a stone was left standing when, in the spring of 146 BC, the starving population was put to death by fire or taken into slavery in the third year of a merciless siege. All that remained intact was what came to light in the rubble burrowed through by the Romans: foundations, burial places, and accidental finds such as a child's doll with wooden-hinged joints or a potter's kiln in which the "kernoi," the ritual oil lamps, had stood on the eve of the decisive battle in preparation for the approaching Demeter Festival. Hardly any written Carthagian remains were found: their whole library was handed over to the Numidian kings during the final looting of the city and has not come to light ever since.

The Romans were responsible for the destruction, but they were also the first to carry out excavations in Carthage when they built their new provincial capital on the site of the ruins some one hundred years later. Tertullian, the early Christian

theologian and writer, reports that they found and opened Punic graves when laying foundations for new buildings at a later date. But the surprising discovery by the German archaeologists was the fact that the Romans completely laid bare the destroyed city before Roman master-builders erected new walls on old foundations, thus leaving the layout of the Punic metropolis intact. The orientation and rectangular building of the Augustan foundation followed without any changes the city extension carried out on the coastal plain during the reign of the House of Mago in the 5th century BC, whereby the building plans were transferred to the slopes. Despite the changed architectural character of the Roman artisans' quarter on top of the large Punic houses dating from the 5th to the 2nd centuries BC, which the German experts explored on their excavation site, there was evidence that Punic building lines and wall substances, and, in particular, Punic cistern installations, were almost all used up to the 7th century AD. It was only at the German excavation site that it also proved possible to trace the history of the development of a Punic dwelling extensively, from the foundation to the destruction of the city by the Romans.

The discovery of traces of the Carthaginian seawall was no less of a surprise. For more than one hundred years archaeologists had searched for it in vain. With its ashlar embedded in sand below the stones, some of which were below sea level, this wall once protected the city from the surging sea and hostile attacks.

Every sandstone block had to be brought by sea from the quarries near Korbous in Cape Bon where gigantic underground quarries were also located near El Haouaria. These quarries were to become the main source of building material for the Romans. The unearthing of several cornice fragments during the excavations provided the incentive to reconstruct part of this colossal edifice which was once 12 metres high. Behind this protective wall, which was later moved forward some 30 metres in the gate area, the new part of Carthage was able to spread and develop into a residential district amidst greenery. The layout, which is known today, gives us some idea of

the pattern and size of the houses. Together with their inner court, some of them had a living area of 1,200 square metres, which was unprecedented in the Punic world. Great care was taken with the sinking of many wells and the construction of cisterns since Carthage relied entirely on rainwater cisterns and deep wells for its water supply and, beneath the wells, the "well of 1,000 amphoras". Not until much later did the Romans construct a 124-kilometre-long aquaduct from Djebel Zaghouan, providing the capital and Antonius Pius's luxurious thermal baths with 32 million litres of freshwater daily.

In order to give modern visitors to Carthage a visual impression of the difficult architectural history of the city, German archaeologists have restored the varying floor levels of a Roman artisan quarter, complete with workshops, cellars and cisterns, above the reconstructed walls of Punic coastal villas with their preserved terrazzo and mosaic floors.

Scientific interest in the glorious past of the city of Dido and Hannibal was first awakened in the 19th century when French archaeologists began extensive excavations in this historic soil in 1857.

Gustave Flaubert brought Punic Carthage back to life in his famous novel "Salammbô" (1862) with its shocking description of the cruel ritual of child-sacrifice. Flaubert was no longer alive when proof of this cruelty was accidently found some 60 years later: in a vault some 10 metres beneath the ground thousands of funeral stelae and clay vessels full of calcified bone ash were discovered. This was the tophet – the consecrated last resting place of some 20,000 unfortunate first-born children killed between the years 400 and 200 BC. They were sacrificed in death by fire to the divine couple Baal and Tanit to keep the wrath of the gods away from the often envied and threatened city and its superstitious inhabitants.

At the request of the Tunisian government, Carthage's restored ruins and excavations were turned into an archaeological park. Since 1984, the "Magon Quarter," i.e. the excavated site with remains of large Punic houses, the Punic seawall and

the Roman street in Cardo 18, which has been restored as a promenade along the seafront, has been open to visitors.

Dr. Gisela Reinhardt-Reuter

Research experts from the Deutsches Bergbau-Museum (German Mining Museum) in Bochum penetrated the heart of hitherto unproven traditions in the modern oilproducing state of Oman on the Arabian peninsula when they discovererd numerous copper-production centres dating from the 3rd millennium BC. Consequently, the researchers were able to prove quite conclusively that Oman is identical with the legendary Makan mentioned in Sumerian cuneiform texts:

Makan: Legendary Land of Copper Discovered

King Sargon of Akkad, Mesopotamia, the self-appointed "King of Four World Landscapes", boasted around 2,300 BC that ships from Dilmun, Makan and Weluhha tied up at the harbour moles of his city. He knew where much-coveted rare commodities could be found and exchanged for his own products. But where were these places, cities, and countries which are mentioned time and time again in cuneiform texts dating from the 3rd and 2nd millennia BC?

Finds helped to link Meluhha with the prehistoric civilizations of the Indus Valley Dilmun. The "Paradise of the Gods" was the island of Bahrain according to research carried out by Danish experts in the early 1960s. It was call and drinking-water depot for shipping in the Persian Gulf. On the basis of these findings, it appeared increasingly likely that copper-producer Makan was located within striking distance of Dilmun. In their deliberations as to whether this place might be located on the southern coast of Persia or the Oman peninsula, the researchers finally concentrated their efforts on Oman after a

Canadian firm, engaged in a prospecting project there, had come across gigantic, mysterious slag heaps and discovered traces of old pits and smelting places. "Copper from Oman" is referred to in Arabic writings by geographer Al-Masudi about 895 BC.

After research work began in 1977, the question as to whether Oman was the Makan of the Ancient Orient provided the point of departure for two fairly large expeditions headed by Dr. Gerd Weisgerber at the beginning of the 1980s.

This undertaking, financed by the Stiftung Volkswagenwerk (Volkswagen Foundation), was concentrated on a site of ruins. These ruins attracted the experts' attention because they featured numerous smelting-furnace fragments, slag, potsherds and exposed copper ore as well as a protective fortification, grave-sites, and wells. This excavation site named after the present-day village of Al-Maysar is situated 100 kilometres south of Muscat, the capital, on the edge of the Wadi Samad which cuts through the foothills of the 3,000-metre-high Oman mountain range at that point.

For the first time ever, and to the great astonishment of the villagers, a hot-air balloon was employed by the researchers. Using the balloon it was possible to make out and register structures, particularly when the sun was in a low position, which could otherwise not be recognized or reached from the ground. Also, the excavations could be mapped photogrammetrically.

By laying bare several of the mud-brick houses, evidence was obtained that Maysan had an entire artisans' quarter, encompassing all crafts from stone mason to potter. The number of metal processing workshops was striking. Apart from the foundation depression of a smelting furnace, a smelting installation came to light in a coppersmith's dwelling. The discovery of a hoard of 22 copper bars and pieces weighing more than six kilogrammes threw much light on the "refinement" and "purification" of the copper mentioned in the cuneiform writings. The bars lay between two fireplaces, apparently ready for further processing. Together with the nearby, semicircular depressions, it is easy to see how the smelting process formerly took

place. Impure copper was melted down in casting crucibles over a flame and then poured into depressions where they hardened into halfround bars. Different types of slag suggest that this process required several stages of production.

In order to be able to produce copper in quantities exceeding domestic requirements which were evidently destined for export, the work and the mining activity, including distribution and transport, must have been well organized on the basis of a sound infrastructure. The heyday of this economic boom, extending from the middle of the 3rd into the 2nd millennium BC, layed the foundations of Makan's fame. During the epoch of this culture, known as "Umm-an-Nar", there were already settlements engaged in agriculture and stockbreeding. Various types of corn seed were sown. Grapes, melons and dates were grown on irrigated plantations. (The fact that dates were consumed as a basic foodstuff is revealed by the traces of decay found in human teeth in graves of that time.) Sheep, goats and Zebu cattle, originally coming from India, were raised as domestic animals, donkeys were used as good pack animals for caravans. Camels were also known.

Fuel requirements for copper production in the 3rd millennium BC apparently presented no problem. If one bears in mind that the local umbrella thorn which grows in the region only provides about 12 kilogrammes of charcoal, the enormous slag heaps suggest that millions of these trees were used for the smelting furnaces. The eventual fluctuating decline in mining over the centuries, until its revival in early Islamic times, may have been more of an ecological rather than a political or sociological problem.

Nothing short of a museum treasure came to light quite by chance when levelling work was being done by a bulldozer. Six hundred individual items, mainly of bronze, were found, including more than 100 carefully decorated bangles and anklets, daggers and vessels. This large number of items could not possibly have come from just one grave, even if many persons had been buried there. It is fairly certain that the site was a cache for the loot of prehistoric graverobbers. This rare collection is now being restored at the Bochum Mining Museum.

More and more discoveries and finds were made in the course of the expeditions, giving proof of the manifold relations between Oman and its trading partners on the Euphrates and Tigris.

The first two seals found in Oman show that the seal was taken over from the major seal-using civilizations in Mesopotamia, including, quite possibly, the decorative motif of a scorpion. But their design and other decorations offer testimony of an independent ancient Omani production of small objets d'art and an astonishing influence of the Indus civilization.

Dr. Gisela Reinhardt-Reuter

In the quest for reflections of past German reality in the language of one of its greatest writers, work began decades ago on a unique dictionary as an all-German venture. It is meant as a presentation of the vocabulary used by Johann Wolfgang von Goethe in his complete works reflecting and interpreting it for our day and age:

The Linguistic Cosmos of a Classical Writer

The first volume of the large *Goethe-Wörterbuch* (Goethe Dictionary) goes from *"A"* to *"azurner Himmel"* in 1,307 closely printed columns. The second volume, which is to appear soon, will probably go as far as *"Einsamkeit."* The large amount of space required for the first letter of the alphabet stems from the fact that so many of the words or word-combinations used by Goethe begin with "a," e.g. *abtrutzen, abkneipen, anbeirufen, anblecken, aneignen, sich aufballen, aufempfinden, aufentzücken, auspochen.* Likewise, the word compounds with the prefix *"all-"* which were favoured not only by Goethe are listed, e.g. *allbelebend, allbeherrschend,*

Allgesang, allgeprüft. There are also words which are used in a different sense nowadays: to Goethe, *Abfall* could also mean *Abhang, abfahren,* among other things, *abgewiesen werden,* whereas the verb *älteln* means *sich benehmen wie im Alter.* The longest article so far, almost eleven columns, is devoted to the word *alt;* Goethe used the word almost 7,000 times.

The joint editors of the Goethe Dictionary are the Akademie der Wissenschaften (Academy of Sciences) in East Berlin, GDR, and the academies of sciences in Göttingen and Heidelberg, Federal Republic of Germany. This major work, setting forth Goethe's vocabulary in articles classified according to meaning, is being published by W. Kohlhammer Verlag, Stuttgart. A total of six volumes is planned with an average of ten to twelve instalments per volume. The first has ten instalments and weighs 3.5 kilogrammes.

Work on the Goethe Dictionary began some 40 years ago as a reaction to a *Denkschrift* by the late Professor Schadewaldt, a classical scholar and Goethe expert. The first editorial team for the Goethe Dictionary was set up in 1946 at the Adademie der Wissenschaften in East Berlin with a subsidiary team in Leipzig. A second team was set up in 1948 by Hans Pyritz, a German language scholar in Hamburg. Finally a third team took up research activities in Tübingen in 1956 where Schadewaldt was a member of the university teaching staff. The scientific and economic responsibility for the Hamburg office was assumed by the Göttingen academy in 1961; the Tübingen team enjoyed the patronage of the Heidelberg academy from 1960 onwards. Initially, the Joachim-Jungius-Gesellschaft (Joachim Jungius Society) in Hamburg, the Deutsche Forschungsgemeinschaft, DFG (German Research Association), and, some time later, the Fritz-Thyssen-Stiftung (Fritz Thyssen Foundation) in Köln funded the work on the Goethe Dictionary. Today, research in Hamburg and Tübingen is being financed in equal shares by the federal and state governments, the state governments being in this case Hamburg and Baden-Württemberg.

The Goethe Dictionary is the second-largest historical dictio-

10

nary of the German language after the Grimm brothers' *Deutsches Wörterbuch* (German Dictionary). It is designed to fulfil a demand by leading German scholars for more than a century, i.e. a dictionary of the vocabulary contained in Goethe's complete works, in addition to the special word-lists and individual interpretations now available. The special 143-volume *Große Weimarer Sophienausgabe (1887-1919)* is used as the basis for the dictionary, but later, revised texts will also be consulted. The linguistic evaluation of the literary works was assumed by the Berlin academy, that of texts on natural science and esthetics and of the conversations by the experts in Tübingen. The letters and official papers fell to the Hamburg team. Together they arrived at a total of 80,000 words, each of which has its own article in alphabetical order in the dictionary. The articles, in turn, are backed up by some three million text quotations.

In the first instance, model articles were written for particularly important Goethe words such as *ahnen, anmutig, Licht, Welt*. Entire monographs resulted from several of these words, showing how such a poet's dictionary can be used by scholars and by readers. In the preliminary research for the Goethe Dictionary, two special dictionaries were used: one on *Werther* and one on *Götz*, which is of particular interest because of its three versions. The first head of the team in Berlin, Hans Georg Hein, started and supervised a bibliography of scholarly treatises on Goethe's vocabulary in card-index form. A concordance of the main Goethe editions has already been completed. It is designed to help readers to find quotations from the Weimar edition in other editions more easily.

The entire team of 17 researchers are indebted to the authors of the Grimm dictionary for both ideas and help, at least in the early days in Berlin. The latter is a "diachronic" work, showing the development of German words vertically, as it were, through the centuries. The Goethe experts, on the other hand, describe their dictionary as a "synchronic" work which provides a "horizontal" selection of the author's vocabulary during seven decades of his life. Goethe lived through an era of intel-

10

lectual and political changes from the Age of Enlightenment to Restoration, an age, in other words, in which the German language was carried to new heights of poetic and scientific expressiveness.

Goethe commanded an especially vast and multifaceted vocabulary emanating from the literally limitless variety of subjects he dealt with. He not only expressed himself as a writer of poetry, drama and prose, but also as a secretary of state, natural scientist and someone who was exceedingly interested in art, history and even Orientalism, as well as in the technology and industry of his time. In his preface to Volume 1, Schadewaldt describes Goethe's works as a "*Sprachkosmos*" (Linguistic Cosmos) in which that deeply historical diversity of ways of speech and forms of expression is combined in the language of one person – a unique phenomenon in German history.

The presentation of this "panorama" based on its "cores," i.e. the words, is the principal objective in compiling this new dictionary which seeks to show the individual use of vocabulary and its context in the language of its time. Simultaneously, it shows how Goethe's language developed during his lifetime: from the "robust frankness" of the young man to the "clarity of maturity," and finally to the "intricate inscrutability of old age." Goethe's vocabulary, covering an era, is also etymologically interesting and can convey important aspects of word formation, usage and meaning. The articles on "primary and characteristic words" are an important instrument for the interpretation of Goethe.

Each article first lists the various meanings of a word, illustrated by selected quotations and lexically annotated. In numerous cases, details are given of historical, biographical, esthetic and theoretical correlations, of context of usage and characteristics of the speakers. These are occasionally supplemented by information on frequency and chronology, etymology and regionalisms. Easily comprehensible abbreviations for the various works and a general dating of all letter and diary quotations provide information about the manner of

text quoted or about the time when it was written. Systematic references to compounds, derivatives and synonyms listed at the end of each article complete the profile of the word in question.

Since language is a living, multidimensional continuum rather than a purely logical system, much latitude had to be observed in interpreting it; the guidelines for interpretation could not be laid down too rigidly. The editors are persons in their own right who view Goethe's language from different aspects. As a consequence, their slogan is: "As short as necessary, as clear as possible." Also, the editors must never forget about the readers and users of such a dictionary which is one of the basic rules of this kind of work.

Dr. Gerda Neumann

A unique atlas designed by German scholars gives for the first time an overall geographical, historical and cultural picture of the Near East. Work on this gigantic project resulted in valuable scientific collaboration with the countries of that region and in plans for a similar atlas of the Arab world:

Atlas of the Near East

Petrol is scarce in Sudan. Only a few litres are allocated each day, making it basically impossible to carry out research work there, says Professor Wolfgang Röllig of the University of Tübingen. But the female scholars from his university managed it: their project impressed the authorities and museum officials in Khartoum so much that the museum collected petrol for several weeks, thus enabling the women to make an expedition lasting several weeks to the Butana region, in the north of the country. For the first time, a unique cultural monument, the 2,000-year-old temple of the lion-god Apodemak, is surveyed, photographed, and sketched. Although this temple was visited by explorers in 1822, it was not scientifically investigated. Today it is severely threatened by wind and sand.

The temple shows the intermingling of the Egyptian and local Meroitic cultures under Hellenistic influence, far removed from Memphis or Alexandria, on the edge of the world as it was known then. This is why it became the object of an exemplary study as part of an extensive research project in which 96 scholars from 14 different disciplines, ranging from Egyptology to Zoology, are cooperating and which has now become known even in Sudan. The study which is being prepared in the Federal Republic of Germany is the "Tübinger Atlas des Vorderen Orients" (Tübingen Atlas of the Near East). The project is being financed by the Deutsche Forschungsgemeinschaft (German Research Association).

This huge cartographic work covers the whole area from the Bosphorus to Hindu Kush, from the Persian Gulf to the Nile, i.e. the present-day territorial states of Turkey, Iran, Afghanistan, Lebanon, Syria, Israel, Iraq, Saudi Arabia, Yemen, Oman, and the United Arab Emirates on the Gulf as well as Kuweit, Bahrain, Qatar and, of course, Egypt. Never before has there been such a comprehensive atlas. Even today, says Röllig, an Assyrologist and spokesman for the special research project, there are literally no national atlases of oriental countries to match those of, say, European countries.

Among other things, the Tübingen atlas covers the relief, hydrology, geology, geomorphology, climate and hydrogeography, flora and fauna, population, settlement, economy and transportation systems of the area. Many pages are devoted to the region's historical development from the Stone Age to modern times. There is a map showing imported goods in the Bronze Age from Mesopotamia, Egypt and Mycenae; another map deals with modern communication systems and tourism; and a third is a language map of Afghanistan. Other maps cover groups of dialects in the Near East and house forms in Lebanon. Some pages describe fishing cultures on the Indian Ocean during the Middle Stone Age (10,000 to 3,000 BC), the architectural history of Jerusalem, synagogues in Israel, or the consolidation of the Umayyad Empire. Other subjects include the magmatism in west Turkey, the variety of forms of a desert

basin in Iranian highlands, pleistocene coastal terraces in southern Turkey, or steppe vegetation, taking inner Anatolia as an example.

The first maps were issued in 1973. In the meantime, there are 132 maps printed on 102 sheets. When the project is finished, the atlas will contain 350 maps on 235 sheets. Research findings which cannot be shown on maps, or which complement them, are given in special supplementary volumes to the atlas. Here, too, the range of subjects is highly diversified. Some 80 have been published so far covering such topics as nomadism, the trading metropolis of Aleppo in Syria, Egyptian dialects, and Islamic cities. There are also supplements containing lists of ancient place names, the taxing of landed properties during the Mamluk Age, and the bryophyte vegetation growing on other plants in the Hyrcanian wooded area of northern Iran.

With many of the maps, a basic approach to the issue had to be worked out first, not only in the archives, but also in the field. Tells were searched systematically for remains from ancient and early history, place and field names were registered, distances measured, ancient water sources tracked down and the present forms of land utilization registered. Soils were analyzed and present-day plant material gathered for the vegetation maps as well as animal remains for ancient history. Very often past and present intermingle during these activities. Thus, the kinds of vegetation existing today allow conclusions to be drawn on the history of the flora.

The experts also talked to nomads, farmers and town dwellers about their living habits and retraced the campaigns (which are known from historical sources) by the Egyptians, Hittites or Arabs in the conquest of Syria. In regard to the problems of early economic systems, questions concerning the relationship between fishing and nomadism are just as important as taming wild animals into domestic animals. German ancient history experts, together with several French and Italian colleagues, examined piles of mussels which suggested that Stone Age living habits prevailed during periods which have long

been considered to have been cultural ages elsewhere. As a result, the Tübingen experts were allowed to dig in Oman to trace links between the nomads who occasionally ate mussels and fish and nomads who lived on hunting.

Other parts of the project led to cooperation between German and local scientists as well as contacts to colleagues and institutions throughout the Near East. The contacts will be of great benefit to German science both now and in the future. The Tübingen atlas has apparently been an incentive for Near Eastern scholars to undertake their own research work. Some countries are not only thinking in terms of atlases for specific areas; an "Atlas of the Arab World" was recently conceived under the aegis of the Union of Arab Universities. During the initial planning stages of this project, the responsible geographers from Arab countries went to Tübingen.

The special research project in Tübingen has filled in many gaps in the map of the Near East, revised the commonly held views of the area's prehistory and history in many respects, and thus laid a solid basis for understanding the present and coming to grips with major current problems in this part of the world. The keywords in this connection are oil exports and water shortage, population explosion and expansion of deserts, economic growth and scarcity of raw materials. At the same time, the Tübingen researchers have made it quite clear just how fragmentary our knowledge of Near Eastern geography, fauna and flora, languages, and history still is. This goes to show almost automatically that, once the work on the Tübingen atlas has been completed, detailed research into the geography and history of the Near East will have to depart from a new beginning and more intensively than ever.

Dr. Renate I. Mreschar

Although a person may know what he wants to do, he cannot fix his objective when trying to solve highly obscure problems, because solutions at which he has already arrived may have changed the overall situation again. This predicament is a challenge not only for a person's planning ability but also for science. Scientists might be in a position to help if they only knew more about the way in which human thought processes are organized. A German scientist has gone about investigating this field in his own remarkable way:

Project: Thinking in Systems

It is not only politicans and planners of urban development or researchers who find themselves confronted with intricate and interwoven problems. In the final analysis, any citizen wishing to find out whether a new traffic highway or an atomic power station is really needed is faced with the same situation. He must be in a position to check up on contradictory information and missing details, plough through mountains of data, weigh confusing analyses, and identify correlations. Professor Dietrich Dörner and his colleagues at the Department of Psychology, University of Bamberg, have been interested for several years in determining how the human psyche responds to such demands.

Within the framework of their project *Systemdenken* (thinking in systems), they confronted persons with complicated situations and observed over a period of time the thought processes eventually leading to action. In his book *Forschung in der Bundesrepublik Deutschland* (Research in the Federal Republic of Germany), commissioned by the Deutsche Forschungsgemeinschaft (German Research Association) and published by Verlag Chemie, Weinheim, Dörner says that this research method differs from the current trends in psychological research. The usual procedure is to examine the details which obviously are not normally isolated from one another in the hope that "by setting up a small wall here, an arch there, and adding a pillar or two there, a cathedral will be the automatic result."

Dörner follows a different path: he goes from top to bottom. He first seeks to obtain an overview of the thought process as a whole which he assumes consists of numerous sub-processes of using information.

Consequently, realistic and complicated problems were created in the form of computer simulation games. The test persons either had to assume the office of mayor and control the fortunes of a small central European municipality called Lohhausen over a period of ten years, or they were appointed as advisers to a region in Tanaland, an imaginary developing country. Both the mayor and the adviser were allowed to intervene freely in the system to achieve their objective, i.e. the well-being of the local residents or improved living conditions for the people living just above subsistence level in Tanaland.

Possible measures in Tanaland included mechanization of agriculture, irrigation, land clearance, wood processing, hunting, or building a reservoir. The mayors, for their part, had the authority to influence, via computer, the manufacturing and sales policies of the municipal factory, change income tax rates, create jobs for teachers and kindergarten staff, set up and lease doctors' offices, engage in new housing projects, and establish recreation facilities. Another system called "Taylorshop" simulated the situation in a fictitious small industrial enterprise, and in a fourth system named "Dori," the test persons were called upon to improve the plight of a nomadic tribe on the edge of the Sahara.

The test persons played their parts with varying degrees of success: many of the Lohhausen mayors provided their town with economic prosperity, while others ruined it, and the majority of the advisers wrecked Talanland, while only a few caused the economy to blossom. But without exception, all test persons had certain difficulties with these complicated environments. They mainly concentrated on current problems, seeking the next-best solutions, but neglected the side or long-term effects. Few of them made allowances for future developments, and if they did they usually based their projections on present data and conditions, assuming that the future development

would be linear. But in real life, says Dörner, exponential and other non-linear developments are the rule in dynamic, complex situations.

If only the extreme groups are considered, there is a marked difference between the behaviour of the successful and unsuccessful problem-solvers. The successful problem-solvers analyze their aims at the outset and settle one problem by a system of inter-related partial decisions. These partial decisions are the basis for other partial decisions and counteract undesirable side-effects. These kinds of problem-solvers usually deal with a particular matter until they have found a conclusion, i.e. they eventually make a decision. The successful test persons control and plan their thought processes to a greater degree than those who fail to complete their assignment; they carefully consider what they should do, and when they should do it, and how effective their previous actions have been.

The poor problem-solvers, on the other hand, base their actions on the "repair service principle." They concern themselves with the first problem coming their way. Thus, their behaviour becomes inconsistent and is fragmented into unrelated and isolated actions. They also make little effort to gather information and tend to back up their own concept of reality behind a wall of dogmas. They jump from subject to subject without coming to grips with one of them, or they withdraw to unimportant sub-areas which they already have well under control. Unsuccessful problem-solvers make impetuous "everything-or-nothing" decisions more frequently than the successful ones. They thus want to force major changes or reassure themselves of their own competence.

The tests have also shown that good problem-solvers are by no means more intelligent and imaginative than the unsuccessful, but that they are more self-confident and inquiring. Their readiness to expose themselves to new types of environment is greater. The fact that they come to grips more easily with them than the poor problem-solvers stems from their natural ability to deal with abstract concepts.

Apart from computer scenarios, the Bamberg research experts are now including authentic, i.e. reconstructed, historical and political situations in their experiments. For instance, test persons are asked to assume the role of Louis XVI in the year 1787, or that of a local government politician called upon to plan the construction of a new hospital. The historical situation is disguised by changing the time, culture, name und place. The behaviour and actions of the test persons, conveyed to the project leader or computer in conversation or by thinking aloud, is recorded and then converted into standard codes so that they can be statistically evaluated. A collection of "cases" taken from daily papers and history provides additional clarification on whether patterns of behaviour occuring in reality are similar to those observed in experiments. The analysis of these various research findings will eventually be combined in a comprehensive theory reflecting as accurately as possible the organization of human thought processes in complicated situations.

Dr. Renate I. Mreschar

In all probability, the future of the world will not depend on shortage or superabundance, but rather on whether commodities are correctly or incorrectly distributed. If two men sit down at a dinner table, and one of them eats a chicken while the other one just looks on, they have, statistically speaking, consumed half a chicken per person. This is, of course, absolutely misleading. The message conveyed by such examples can be more effectively applied in practice if the appropriate strategies are developed with the help of computer models, taking political aspects into consideration. This is what the Berlin GLOBUS project is doing to an unprecedented extent:

Decision Aids for the World's Future

The story of the chicken which was shared "fairly" only statistically was told by Professor Karl W. Deutsch, the former director of the International Institute for Comparative Social Research at the Wissenschaftszentrum Berlin (Science Center Berlin). Since 1976, a research team in Berlin headed by Stuart A. Bremer, Ph. D., has been developing a computer simulation world model entitled "GLOBUS" (Generating Long-Term Options By Using Simulation). This model may well prove of valuable assistance in the political decision-making process. The function of such world models is to provide information on possible future developments, i.e. the anticipated long-term effects if present conditions were to persist or if the behaviour of one or more countries were to change in one realm or another.

So far, according to Deutsch, simulation runs by GLOBUS give rise to "guarded optimism" for the next 20 to 40 years. Mankind will not perish due to an absolute shortage, the Club of Rome study entitled "The Limits to Growth" notwithstanding. "If we perish, it will be because of the deviations, the differences, the contrasts, our inadequate distribution system, our political inability to keep the differences in the world in check." This applies, Deutsch states, just as much to demographic growth as it does to hunger, military matters, etc.

Despite the increasingly evident realization that the world's major problems are more of a socio-political rather than a purely material nature, no world model so far has given politics and economic policy due consideration. The GLOBUS model is the first to highlight the political and economic behaviour of governments. In other respects, it embodies a further development of earlier models. GLOBUS is designed to make computer forecasts of long-term political and economic strains and bottlenecks, as well as point up alternative courses of action through the year 2010. Some of its focal points of attention are: national fiscal policy (government expenditure and distribution policies), domestic protest and violence, security and foreign policies, world economic relations, and North-South relations. The interactions among these factors are defined on the basis of empirical data from the last three decades. Development and application of the model will continue over the next few years in an effort to enhance its overall structure.

GLOBUS comprises 25 of the world's 150 nations. Together, these account for 74 percent of the world's population, 80 percent of world production, 85 percent of military expenditure, 67 percent of world exports, 57 percent of political protests, and 68 percent of hostilities between nations. Another criterion for their selection was the fact that each of the 25 GLOBUS nations is important in its own right, independently of the conflicts between the major powers. The 25 nations are divided into four clusters: the industrialized West (Canada, Federal Republic of Germany, France, Great Britain, Italy, Japan, USA); the South (Argentina, Brazil, China, Egypt, India, Mexico, Pakistan, South Africa, Turkey); OPEC (Indonesia, Iran, Nigeria, Saudi Arabia, Venezuela); and the Eastern Bloc (GDR, Poland, Czechoslovakia, USSR).

A special quality of GLOBUS is the fact that trade among these 25 nations is portrayed bilaterally, embracing six types of goods. The same holds for two forms of foreign policy behaviour, namely conflict and cooperation. This means that 5,200 bilateral relationships have to be depicted. Two submodels serve as transmission mechanisms, i.e. as distributors

of flows in the sectors of foreign policy (the exchange of conflict and cooperation) and foreign trade. In addition, each of the 25 national models consists of six submodels (modules), covering demographic development, foreign trade, foreign relations, domestic economy, domestic policy, and the expenditure and revenue policies of governments. In other words, GLOBUS is a "family of models." This facilitates the simulation of manifold interactions and alternative interrelationships as well as national models of varying complexity. Furthermore, GLOBUS is so structured that it is possible to remove one of the GLOBUS nations and replace it with another. In this way, GLOBUS can, in principle, be applied to the problems of countries and regions not included in the model at the present time.

How does such experimental anticipation of conceivable future developments take place? In so-called "standard runs," a computer forecast is made of the way in which the world might develop should things continue as they are. On this basis, stated aims (regarding economic growth, for instance) or assumptions about specific, significant changes in development (such as declining demographic growth or reduced East-West tensions) are formulated as scenarios and introduced into the model. The corresponding computer runs then show what could happen if these assumptions became reality. Three different scenarios on Western defense expenditure and three scenarios on economic protectionist measures have already been implemented. In the defense study, a unilateral 6-percent annual increase in armaments from 1980 on triggers an arms race, almost doubling world-wide military potential by the year 2010. A three-percent increase would cause the global armament level to rise only marginally, while a defense budget "freeze" at the 1980 level would actually lead to a slight arms reduction with a shift in the military balance of power towards the Eastern Bloc (as opposed to a shift in favour of the West in the 6-percent scenario). International hostilities would increase at both 3 and 6 percent, while in all three scenarios – and this outcome is the greatest source of apprehension – the

militarily weaker nations would not relent in their efforts to "catch up."

Dr. Renate I. Mreschar

There is a possibility that a new scientific discipline, synergetics, will help to transform the concept of disorder into a new and creative form of intellectual "disorder." This "disorder" will pull individual issues out of firmly established systems of thought which were actually considered to have been settled a long time ago. It will reveal new aspects of issues which may lead to surprisingly new solutions in many areas of science:

When Chaos Is No Longer Chaos

Growing criticism has been levelled at the useful and clearly defined finding in thermodynamics on the growing entropy of inanimate systems. It clearly states that a gradually increasing pattern of disorder which cannot be reversed on its own emanates from every pattern of order. This is true not because living processes have the exceptional property that they literally turn all disorder into order, but because of the fact that there are processes in inaminate physics which may aptly be described as self-organization. These processes occur in the socalled "open systems" which are accessible to energy and matter.

There are enough examples of this. Take boiling water in a saucepan: at certain temperatures it does not swirl around disorderly but flows in an "organized" structure of fluid cells resembling a honeycomb. There is not the slightest indication of the instability, known as Bénard instability, in cold water.

Another example are the processes involved in the discharge of light by a laser whose coherently oscillating light waves are suddenly "present." They can only have been emitted by atoms which some still unknown systematic force abruptly removes

from their state of disorderly, individual oscillations, prompting them to march in step like a squad of soldiers.

Professor Hermann Haken of the Department of Theoretical Physics at Stuttgart University is the inventor of synergetics. Synergetics is the theory of combined effects, by means of which the underlying reasons for phenomena of this kind are to be ascertained. Reduced to simple terms, the phenomena already investigated indicate that when researching inaminate processes it does not always suffice to analyze a complicated system by examining its subsystems and then merely regarding it as the sum total of the properties of these partial systems.

On the contrary, the two examples of heated water and the laser point to the surprising fact that partial systems of this kind work together in an orderly fashion and, in their entirety, are able to develop properties which can neither be observed nor even imagined in any one of these subsystems on its own.

Synergetics is expected to give basic answers to the question of how this cooperation between various parts, atoms, molecules, cells, groups of cells, economic system parameters, animals, humans, etc., new types of structures, or behaviour patterns in the widest sense comes about and functions through self-organization. Synergetic research has been consistently promoted by the Stiftung Volkswagenwerk (Volkswagen Foundation) in Hannover under the provisions of a major grant since 1980.

In the meantime, Haken's textbook "Synergetics," outlining the theory of combined effects, has resulted in new terminology which would hardly have been associated with mathematics and physics in the past. This is true, for instance, of the word "enslavement": in the case of the laser, atoms are forced to oscillate coherently by the very light they produce themselves.

Correspondingly, there are phenomena in the inanimate physical world which distinguish themselves from theoretically similar phenomena by being "more equal" than others. They occur in larger numbers than the others, thus forcing an entire system into a stable state of self-organized order.

The complicated mathematical description of such processes

has now made great advance. Possibilities of application, in addition to determining facts which will, of course, always remain important, reveal themselves when the problem is reversed. For if we ask what the properties of the parts of an intricate system have to be like to form new, desired functional patterns within this system through self-organization of their previously hidden special aspects, this new road becomes clear.

In this connection, Haken also concerned himself with pattern identification in electronic data processing and designed, among other things, a synergetic computer system. Such a system would put an end to the currently held belief that purposive distribution of labour in analogy to the traditional, hierarchical structure in offices, can be achieved with a large computer system only if there is a superordinate head computer which "manages" the entire system, allocating work to subordinate computers and controlling them.

If a synergetic system were used, the network of computers could, so to speak, work together along democratic lines since their entire external and internal activities could be used as a basis for individual self-organization into a superior functional unit. This is undoubtedly a goal which has been set very high, but Haken reckons it is achievable in principle.

Basically, this issue once again shows the actual purpose of synergetics. This discipline refuses to regard system studies as accomplished by studying subsystems; it traces the behavioural patterns of such systems back to the factors of order and the possibly "privileged" processes which actually determine their overall functional manifestations.

In the final analysis, this could consequently lead to revolutionary developments in many fields since paths are mapped out which go far beyond the actual research area of mathematics and the exact sciences. In the economic and social sciences, for example, there is a great number of these fascinating behavioural patterns of systems whose fundamentally influential order and organizational factors have to be ascertained. As Haken once wrote, the research experts in these

disciplines are already working intensively on the other side of a tunnel into the mountain of synergetic findings.

The final sentences in Haken's book entitled "Successful Secrets of Nature" suggest that research will probably not end here. He draws attention to an aspect which is intriguing from the points of view of the humanities and epistemology: "Again and again we had to expect coincidental occurences during the formation of new organizational states, which, indeed, often finally determined the new state. Here we are facing the problems which have not yet been explored by any means. Should we actually say that the occurence of a special laser oscillation is a matter of pure chance, but that of a biomolecule is not?" As Haken suggests, it is at this point that a fundamental limit to man's knowledge emerges. In the field of natural sciences, and even more so in the philosophical and sociological areas, there are problems which, in principle, cannot be solved or cannot be solved conclusively.

Rolf H. Simen